NASA Tech Briefs

National Aeronautics and
Space Administration

November/December 1986

Special Edition

NASA Computer Previews '87

The Leading Edge

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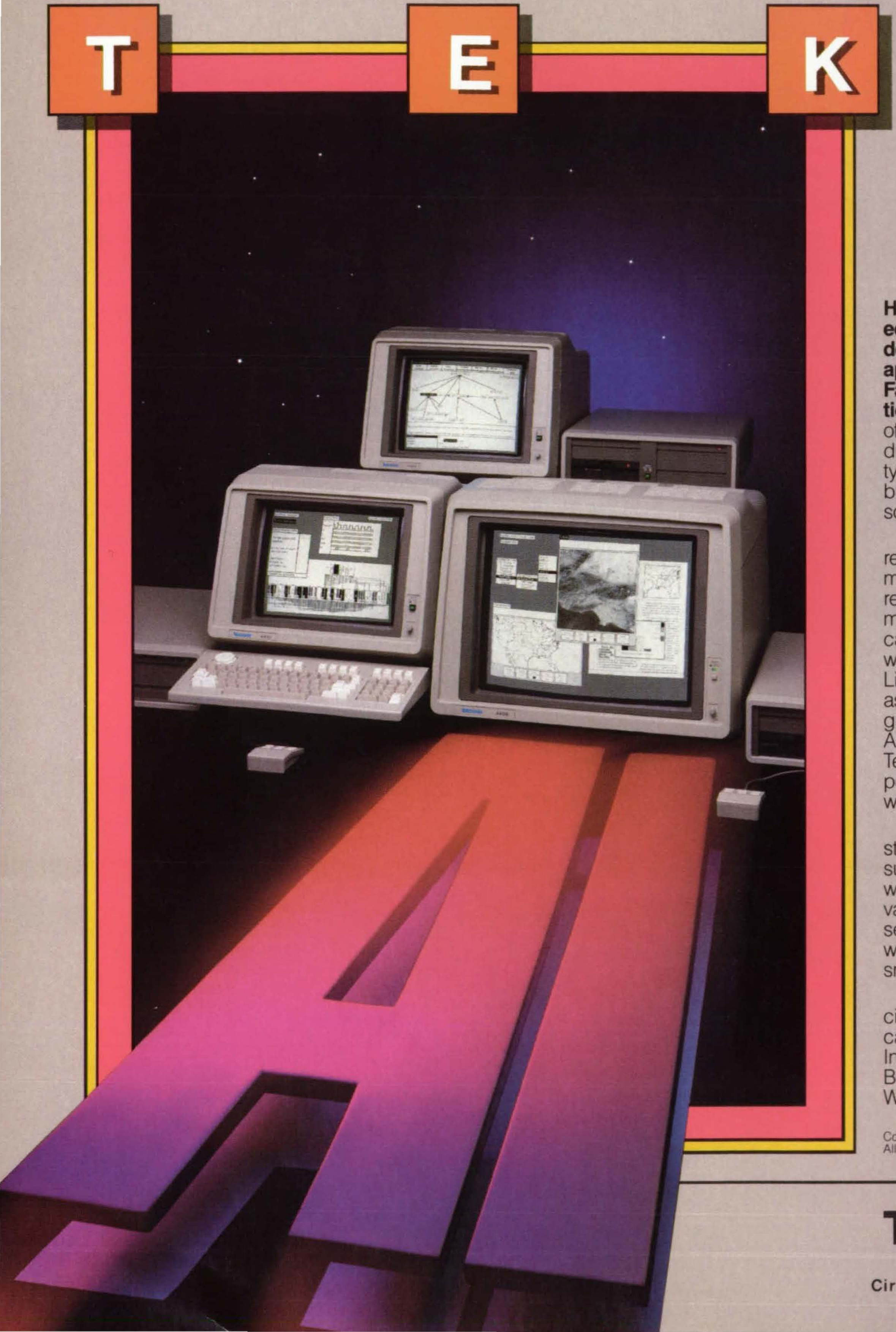

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National Aeronautics and Space Administration

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NOVEMBER/DECEMBER 1986
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Special Features and Departments

On the cover: Dr. William F. Ballhaus, Jr., Director of the NASA Ames Research Center, is standing with the Cray-2 supercomputer, the initial high-speed processor for the Ames Numerical Aerodynamic Simulation (NAS) system. The NAS description begins on page 20.

At Kennedy Space Center, expert systems will help plan launches around severe weather. More information on NASA's artificial intelligence applications can be found on page 24.

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POSTMASTER: please send address changes to NASA Tech Briefs, 41 E. 42nd Street, Suite 921, New York, NY 10017-5391.

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Editorial Notebook

As regular readers of NASA Tech Briefs will have gathered, this is no ordinary issue of NTB. Our research has shown that well over 70% of our readers buy or specify computer hardware and/or software. The number of readers who use computers on a regular basis is even higher than that.

Moreover, our readership is literally growing daily, and more than half of the people who now receive NTB did not receive it two years ago. A number of these newer readers have mentioned that they really like the magazine, but also wonder what they've been missing. Add to that the fact that computer-related editorial material ranks high on the interest list in every survey we've taken, stir in the general interest in what NASA's doing on the computer front, and you have the reason we decided to publish this special issue, NTB's Computer Previews '87.

We've tried to present a taste of what's going on at NASA vis a vis computers. We've reprinted a number of what have historically been the most requested and/or most important software briefs, which I've called, for want of a better term, Golden Oldies. We've got a feature on COSMIC, the great NASA software library, and another on AI, as well as articles on other computer-related subjects. We've also added an area where suppliers are able to give you a little information about what they have to offer. You will also soon note that there are no tech briefs that are not computer-related.

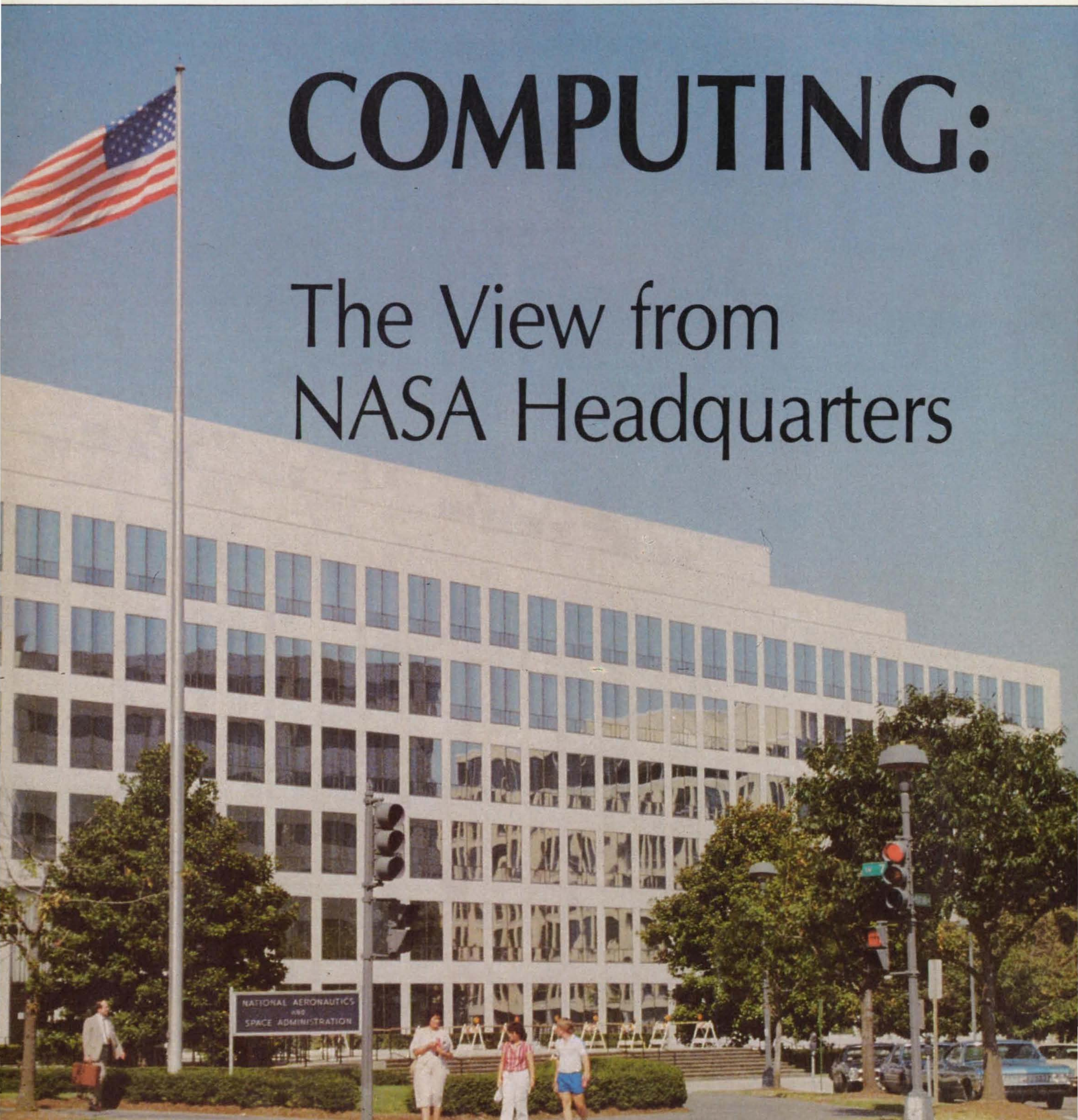
It's a radical departure for us, and we'd like to get your reaction to our doing a once-a-year or occasional issue like this. I do want everyone to understand that this issue in no way supplants our regular publication of NASA Tech Briefs. We were scheduled to publish but six regular issues of NTB this year, all of which you have already received. This issue is, then, "value added". . . or at least that is how we hope you will perceive it.

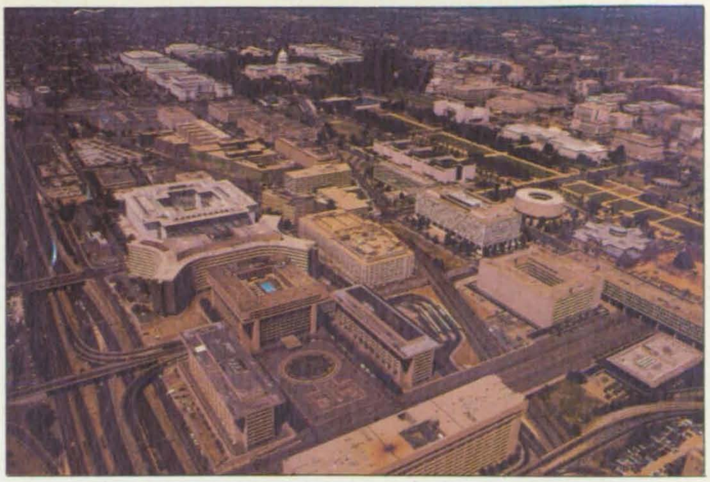
In 1987 we plan to publish 10 regular issues of NTB. Those of you who have been regular readers for some time will remember that when we first commercialized NTB in 1985, we published quarterly. Provided that all goes well, and we see no reason why it should not, we should become a monthly publication in 1988. I cannot reiterate enough that this is our magazine. Let us know what you do and don't like about it. We keep pushing the envelope. Help us, if you will.

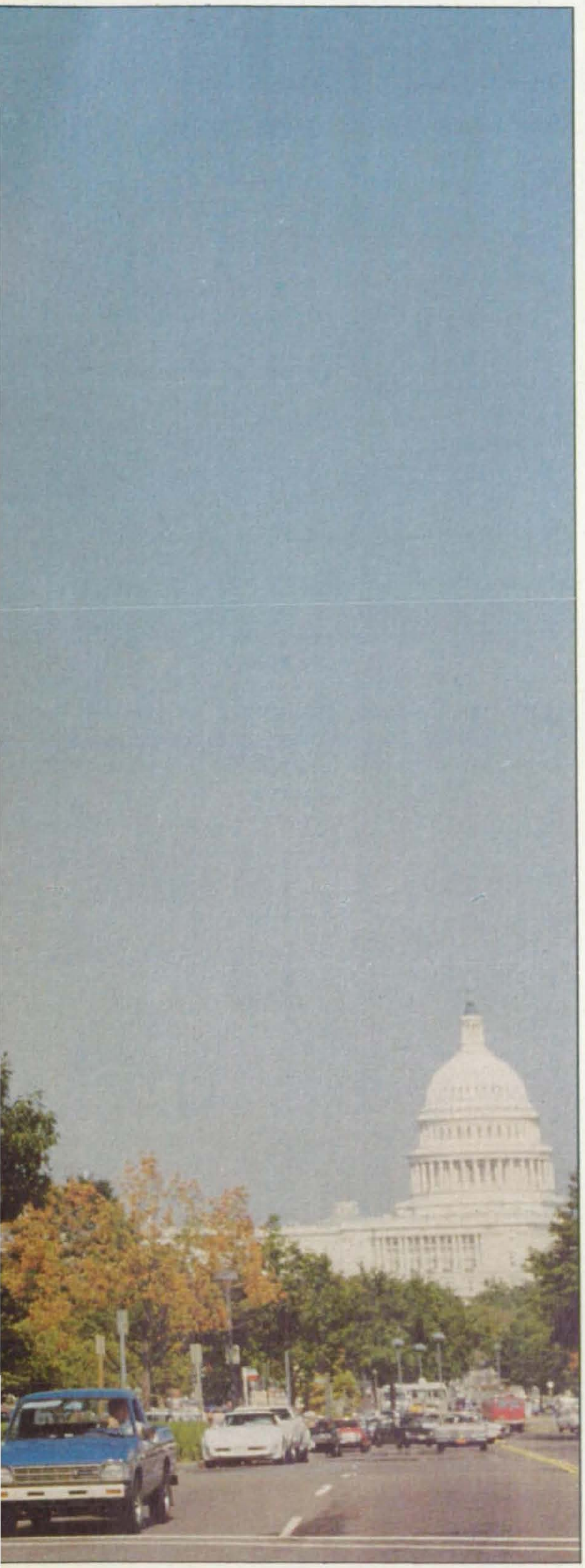
How? Keep the cards and letters coming. □

COMPUTING:

The View from NASA Headquarters







The National Aeronautics and Space Administration Headquarters, located between the Washington Monument and the Capitol, determines Agency programs and projects, establishes management policies, and reviews and analyzes all phases of the aerospace program.

Make up a list of the leading contributors to America's growth in high technology and NASA would surely be among the top entries. For more than 25 years, NASA's requirements for its manned and unmanned space programs have inspired major breakthroughs in engineering, science and medicine. NASA's programs have nurtured astounding growth in a number of industries, especially in companies involved in the development, use and manufacture of computers.

Today, through the leadership of NASA Headquarters in Washington, D.C., NASA continues to break new ground in the use of computers to solve difficult technical problems in disciplines related to space and aeronautics. NASA also devotes a significant portion of its resources to develop methods to make computer software more reliable, cost-effective and reusable, and to increase the overall productivity of the agency through the use of computers. All of these activities are a part of NASA's mission to "conduct aeronautical and space activities for peaceful purposes for the benefit of all mankind," as prescribed by the National Aeronautics and Space Act of 1958.

It's difficult to think about NASA's high technology programs without acknowledging the central role that computers play in many of them. It's just as hard to imagine a time when NASA did not depend on computers to accomplish the goals of its research and space programs. Yet Project Mercury, America's first manned space program, was in progress years before the first pocket calculator was sold. Space flight without an on-board computer? There was no computer aboard the single occupant Mercury spacecraft. Today the Space Shuttle relies on five on-board computers to handle all phases of its flight, from ascent to reentry. NASA's use of computers in other areas has also changed dramatically. The agency is developing new computational capabilities to study aerodynamical phenomena related to vehicle design. NASA is conducting research in electronics, computer science, artificial intelligence, and robotics for increased use of automation, improved information processing and advanced communications systems.

All of this work is planned, directed and coordinated by NASA Headquarters through a number of program offices. The operational aspects of NASA's work in aerodynamics and space are performed at its field centers throughout the country. Each installation has a specifically described mission, with related tasks, and is allocated the resources for their accomplishment.

Some of the major computing activities at the NASA Centers are centered around theoretical analysis, computer-aided design/analysis, real-time flight simulation, and test data acquisition and reduction.

Theoretical analysis and simulation in the disciplines of fluid mechanics, avionics, acoustics, structures, and atmospheric model- ►

ing depends heavily on the use of ultra high speed, large memory, advanced scientific computer systems. To meet this demand, NASA Headquarters is planning for a variety of computational facilities containing state-of-the-art supercomputers.

In a major bid to advance the frontiers of computational analysis, NASA is developing the Numerical Aerodynamic Simulation (NAS) system. Its goal is to provide a testbed for developing new techniques to tackle complex computational problems. The NAS system will consist of a network of high speed processors anchored by the CRAY-2 supercomputer.

NASA Headquarters' emphasis on research productivity is increasing the use of computer-aided design and analysis tools. These tools will allow engineers to evaluate and refine promising advanced aircraft and space vehicle configurations from concept to detailed design while minimizing the need for expensive model design and laboratory testing.

Real-time flight simulation is accelerating the development of new aeronautical controls for aerospace vehicles. Simulation uses mathematical models of vehicle aerodynamics, controls, propulsion systems, structures, avionics, and environmental characteristics. Computer controlled displays and kinesthetic cues provide pilots with a realistic, ground-based cockpit in an environment approaching that of actual flight.

Experimental data collection and reduction is a fundamental part of most research and development activities. Wind tunnels, airborne experiments and remote sensing systems generate enormous amounts of data that often must be analyzed in real-time in order to control the experiment. As experiments increase in complexity and sophistication, significant increases in speed, reliability, and complexity of the data acquisition and reduction systems are required.

Two important computer related Headquarters programs, the Software Management and Assurance Program and AIM, deal with reliability and productivity. While not as well publicized as NASA's space accomplishments, these two programs are confronting challenging problems whose solutions are vital to the ability of NASA to carry out its overall mission.

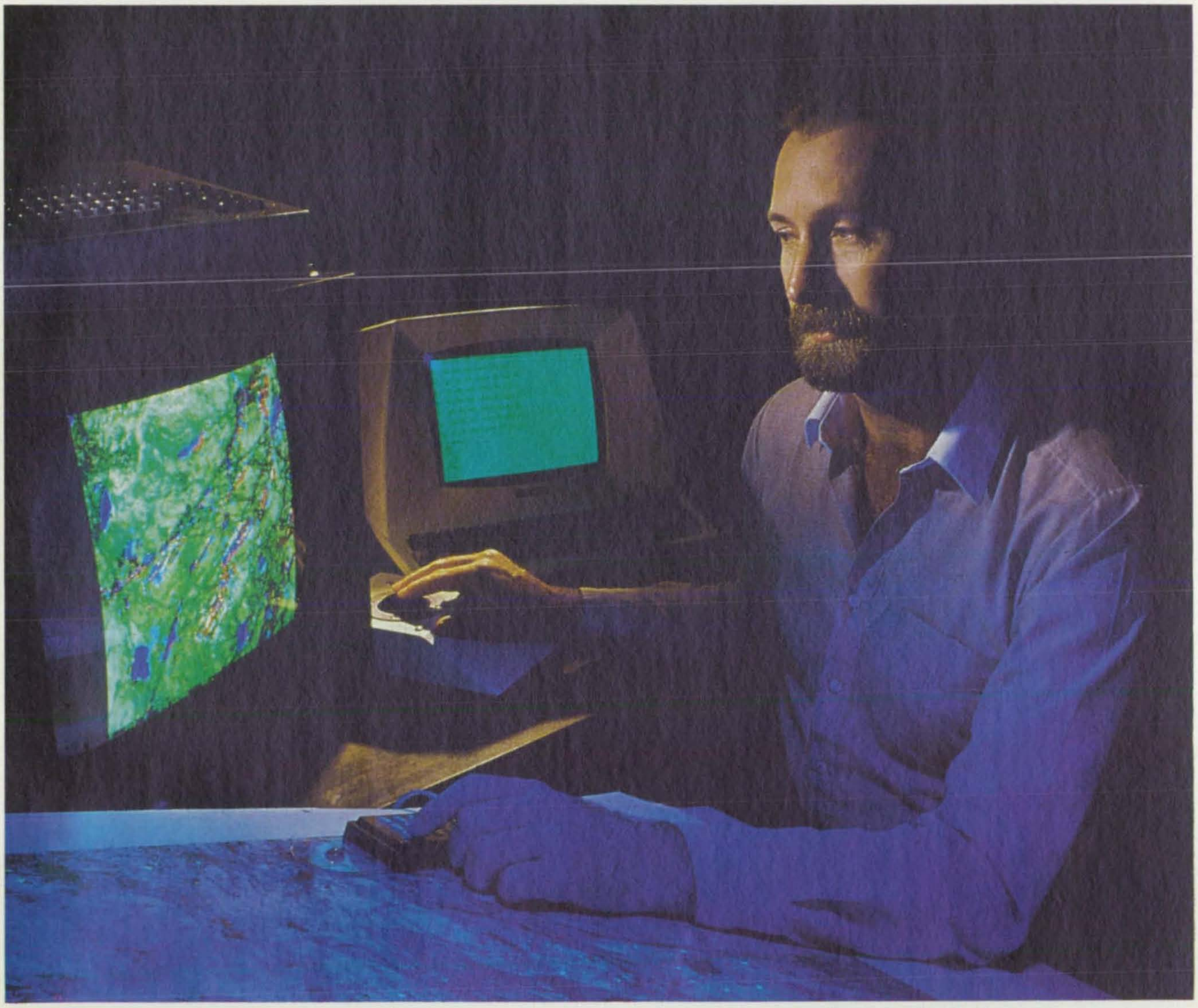
The Software Management and Assurance Program (SMAP) is concerned with assessing and improving software practices used on major NASA projects. The program is directed by the Office of the Chief Engineer at Headquarters and concentrates on software policy, software engineering tools and techniques, human resources and information exchange.

NASA's Automated Information Management (AIM) Council is trying to increase the productivity of administrative personnel and to automate the administrative functions for the entire agency. Dr. C. Howard Robins, in the Office of Management at Headquarters, is the AIM Council Chairman. According to Robins, "The percentage of NASA's budget being spent on information systems has at least doubled in the last five years. Information systems now account for 10% of NASA's budget." In listing the conditions contributing to rising costs, Robins indicates that "the growing cost of software and maintenance has more than eaten up the difference in hardware cost reductions." Robins is optimistic, though, that the AIM Program can help to reduce these costs and allow the agency to make better use of its precious resources.

These are just a few of the many research and development projects that NASA Headquarters is currently planning, directing and participating in. Further details on these and other projects appear in articles elsewhere in this issue. □

Earth Resources Laboratory Applications Software—

Versatile Tool for Data Analysis

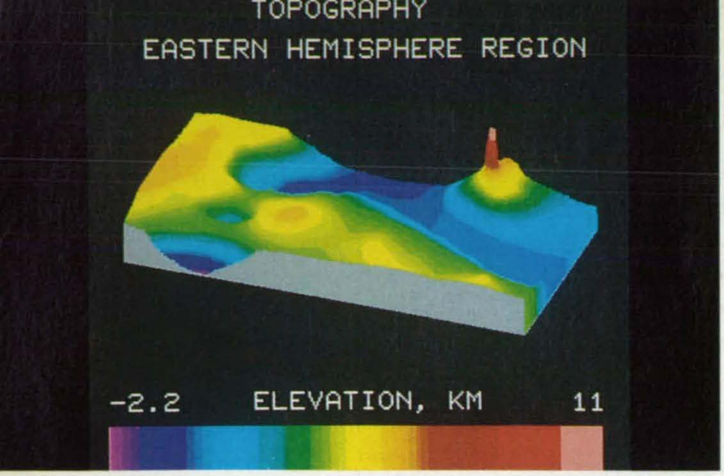


Using the Earth Resources Laboratory Applications Software, a technician computer-enhances a Landsat image to include geographic coordinates.

Taking 98.9 minutes between sunrises, a Landsat satellite orbits at an altitude of 438 miles. Along each orbital path, the Thematic Mapper (TM) sensor scans an eight million acre swath with a resolution or cell size 30 meters square. Complete coverage of the earth is achieved in 233 orbits; sites receive repeat coverage every 16 days. The TM sensor measures and records blue to mid-infared reflected light energy and emitted thermal energy.

Each cell, equivalent to a pixel on a digital display, contains seven raw data values which must be manipulated to produce useful images. The Earth Resources Laboratory Applications Software (ELAS), developed at NASA's National Space Technology Laboratories, was especially designed to analyze and process this multispectral digital data.

Because ELAS processes digitized



ELAS software is used to interpret Mars images transmitted by the Viking orbiter.

data, it has applications that range far beyond interpreting Landsat information: Aircraft-acquired scanner data, digitized topographic data, soil types and rainfall information; any information that can be stored in digitized form. As an integrated image processing and data base maintenance system, ELAS offers the remotely sensed data user a wide range of easy to use capabilities in the areas of land cover analysis.

Composed of 300 separate executable programs, or application modules, and an operating subsystem, ELAS is meant to be as variable as possible. For easy changing from one application to another, the operating system handles all input/output functions, system control functions, and applications module swapping when necessary. The versatile operating subsystem and the available application modules allow users to perform an unlimited variety of land cover analyses, as well as data base construction and manipulation.

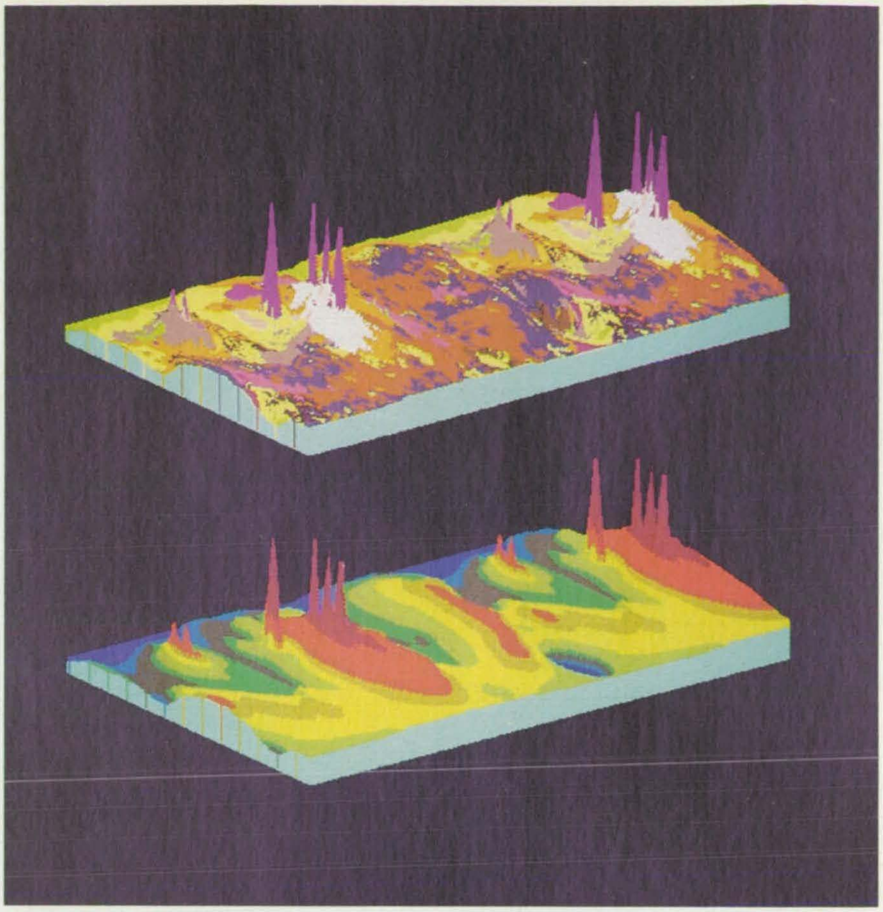
ELAS User Group

In 1983 the NSTL Earth Resources Laboratory (ERL), which authored the original ELAS software and documentation, helped form the worldwide ELAS Users Group. The Group disseminates information concerning the ELAS package, and assists users who are just beginning to implement the software.

Annual meetings are held at NSTL, where improvements continue to be devised and added to the ELAS software. Providing a forum for the user community to exchange information on any aspect of the program, the meeting is an opportunity for synergism of the finest kind. According to Sid Whitley, Deputy Director of the ERL, "We've found that if a geologist develops something, the agronomists or the hydrologists or the geographers are looking eagerly over his shoulder; they try it to see what utility it has for their own applications. It makes little difference what the algorithm was developed for; it finds its way into the other disciplines as well."

Whitley sees ELAS with continually improving and increasing capabilities, mentioning that ERL personnel are "always improving documentation, based on user feedback." Software additions are made frequently, a result of on-going research and development at ERL.

With a well structured and enthusiastic user group, and a highly supportive central clearing house for software improvements, this versatile program is a real winner, a fact supported by its longevity. To learn more about the Earth Resources Laboratory Applications Software, or to obtain a copy, contact NASA's COSMIC, mentioned on page 43 of this issue. ☐



At the Center for Earth and Planetary Studies in the Smithsonian Institution's National Air and Space Museum, Dr. Thomas R. Watters, a research geologist, makes use of the Earth Resources Laboratory Applications Software for planetary studies. With "Mars Consortium Data" garnered from the Viking orbiter, Dr. Watters examines such information as topography, thermal data and albedo, using a variety of classification schemes afforded by the software. Here are two three-dimensional perspective views of the Mars topography. The upper perspective is color coded with the geologic units of Mars, while the lower is color coded topography.

Showing only the most significant surfaces, this computational model simulates airflow around an F-16. To compute the Navier-Stokes equations, a grid is constructed around the aircraft's geometry. The equations are computed at each node (the intersecting lines) of the grid. Increasing the number of nodes gives a more accurate simulation.

SUPERCOMPUTING AT AMES RESEARCH CENTER

A Cray-2, Serial Number 2, the most powerful supercomputer in the world, sits in Building 233A at the Ames Research Center. The Cray-2 cornerstones the Numerical Aerodynamic Simulation (NAS) Program, which serves as a national supercomputing facility. This acquisition represents the first major milestone of the NAS, forming the initial operating configuration of the NAS Processing System Network.

The genesis of the NAS program goes back to the middle seventies when Ames computational fluid dynamics researchers realized more advanced supercomputers were needed to solve their fluid physics equations. Computational Fluid Dynamics (CFD), used in aerospace vehicle design, combines fluid physics, computer science and applied mathematics. With wind tunnel tests, CFD is an important tool for understanding the forces acting on aerospace craft and their engines.

The researchers defined the future NAS as an ongoing, continuously upgraded program. Three objectives were set:

1) The NAS program would provide a computational capability to ensure leadership in CFD and related disciplines, available to NASA, Department of Defense, other government organizations, industry and universities;
2) Continuous hardware and software upgrades would maintain state-of-the-art facilities;
3) The NAS program would provide a strong research tool for NASA's office of Aeronautics and Space Technology.

NAS has been in "Initial Operating Configuration" since July, 1986, when the Cray went on-line at Ames. With

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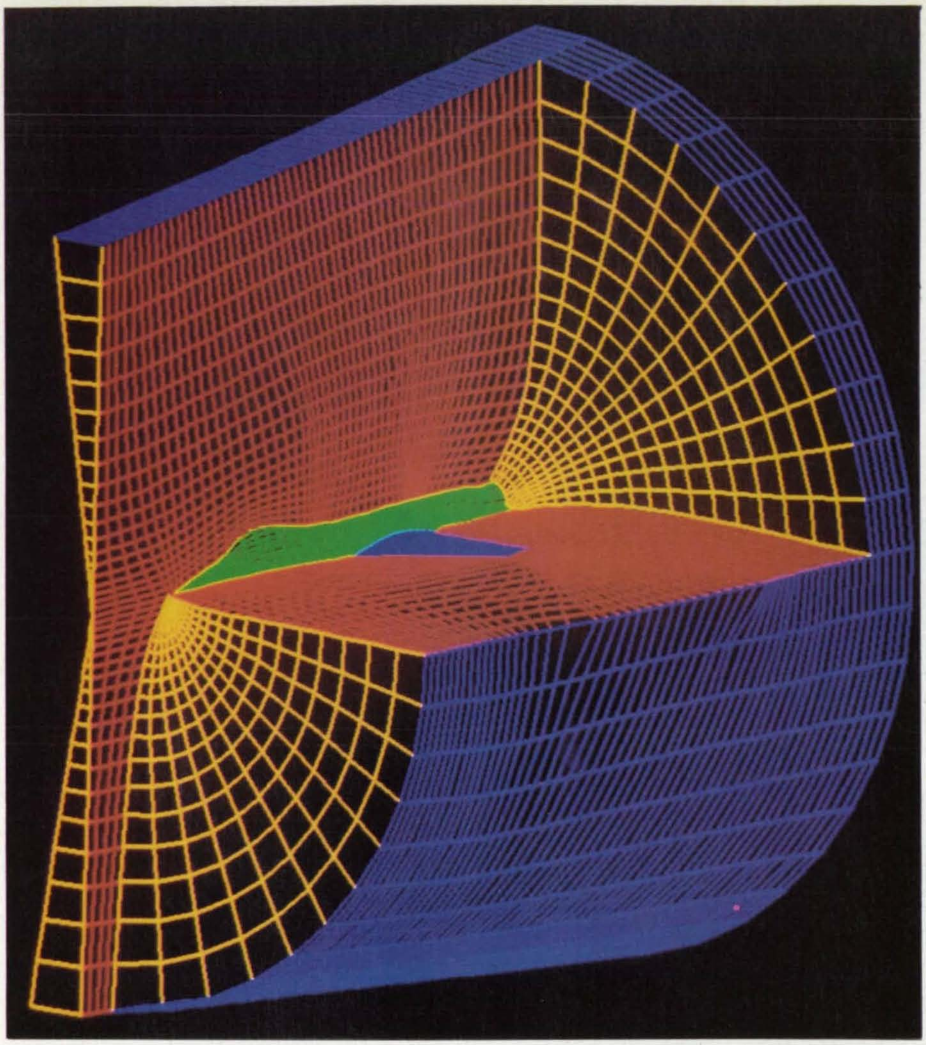


Using particle traces to display the flow physics, vortical patterns created by the strake and leading edge of an F-16 are shown. The particles are color mapped according to their elevation above the wing, providing a three-dimensional view of the vortical interactions.

an upcoming move to a dedicated facility and subsequent testing, the NAS will begin full operations in March, 1987. The NAS Cray has a sustained computational rate of 250 million floating-point operations per second (Mflops), as opposed to a burst speed of approximately two billion Mflops. Supercomputer qualities include a 256 million-word central memory and a 4.1 nanosecond clock-cycle time. The system configuration includes two Amdahl 5840 computers, four VAX 11/780, and 30 Silicon Graphics IRIS workstations. Frank R. Bailey, Manager of the NAS Projects Office, explains one of the benefits of the configuration: "An important thing about the system is that all these computers are networked together, they all use the Unix operating environment."

The Advantages of Power

The degree of computing power inherent in the NAS has proven its worth. Says Bailey, "We've demonstrated the great advantage of a very large memory capacity supercomputer. NAS users are able to approach problems they've not been able to consider before."

Bailey mentions that the NAS is the first opportunity to exploit high performance graphics workstations and supercomputers operating in a cooperative, symbiotic manner. This allows task division between the supercomputer and workstation so that each is performing its function optimally. For example, large scale calculations on a complex model such as viscous flows around an F-16 are computed on the Cray-2. The data from that calculation can be abstracted for display on the workstation.

By rapidly sending results from the Cray to the workstations, which themselves can do interactive graphics manipulation, the system can display three dimensional perspective graphics. The rapid response time gives users immediate feedback to the results of their calculations.

A nationally available resource, the NAS is on-line through a sophisticated set of communications devices, including NASA's Program Support Communication Network, (PSCN). Through NASnet, connecting remote Ethernets to the Ames Ethernet, remote users have "all the capabilities someone locally in the NAS facility would have," according to Bailey. NAS also accesses MILnet and ARPAnet, run by the Defense Communications Agency. Bailey's goal is to be able to access all the available networking within the government infrastructure.

One of the most striking examples of this pioneering remote access technology is the use of the "Dialup 56 kilobit Service." This enables remote users to connect to a NASA PSCN gateway over commercial telephone lines. Connected to NAS at a relatively high bandwidth, users can simply hang up when they're through.

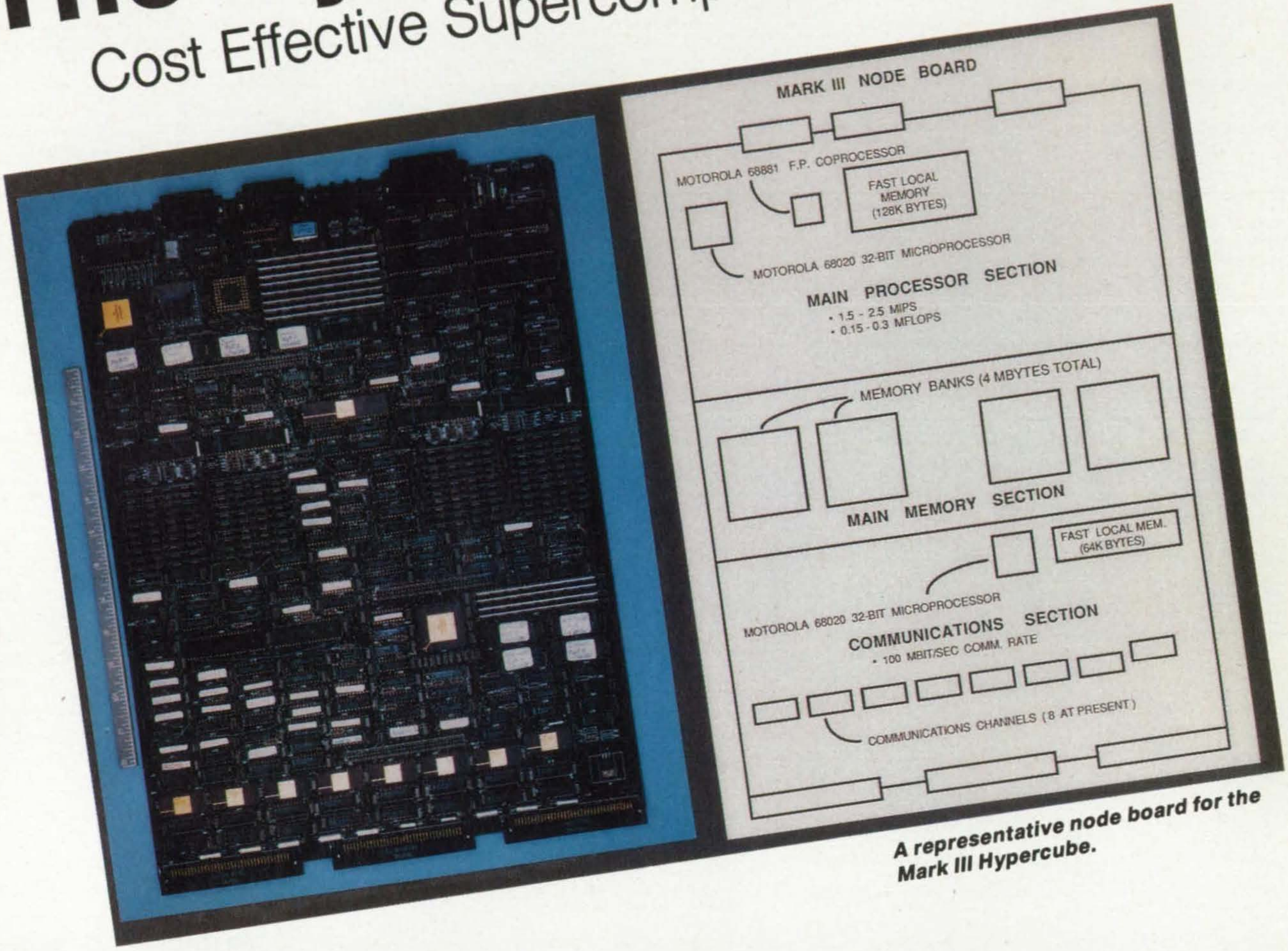
In the Future

Staying at the cutting edge of advanced scientific computing systems is a primary NAS goal. Bailey's acquisition plan includes a sequential improvement of the High Speed Processors (HSP) in the NAS. HSP-1, the CRAY-2, is the first of the high speed processors. The next generation HSPs will be integrated to the facility this fiscal year, giving it two HSPs, one each of the first and second generation. HSP-2 will be able to perform 1000 Mflops, and should have a central memory capacity of one billion words. Bailey foresees a performance increase of four to five times with each generation.

A decade of study has resulted in a state of the art supercomputing facility at NASA's Ames Research Center. The recent acquisition of the Cray-2 represents a major milestone in the NAS program. Intended to advance aerospace research and development through the field of computational fluid dynamics, the NAS includes the ability to support supercomputer-generated large-scale aerodynamic flow simulations with powerful workstations, high-resolution graphics, and high-bandwidth remote communication links to nationwide remote sites. □

Any researcher involved in U.S. industry, academia or government aerospace programs can apply for access to NAS resources. For the operation period beginning in March 1987, applications are available from Leslie Chow, User Interface Manager, NASA Systems Division, Mail Stop 233-1, NASA Ames Research Center, 94035. Potential users must demonstrate a requirement for the unique capabilities offered by the NAS.

The Hypercube—
Cost Effective Supercomputing



A representative node board for the Mark III Hypercube.

A new and exciting area of research at the Jet Propulsion Laboratory's (JPL) Advanced Microelectronics Program (AMP) involves the investigation and development of concurrent computers to attack computationally intense problems. The power promised by this type of computer can be applied not only to well-understood numerical applications, but also to the more complex problems that are found, for example, in expert systems and artificial intelligence.

It has been recognized for some time that substantial (i.e. order-of-magnitude) increases in the computing speed of future-generation computers will be attained only through the development of concurrent, or parallel, computation. Ultimately the various components within a single Von Neumann-type machine cannot communicate with each other at greater than the speed of light, a limit now being pressed (in Von Neumann machines instructions are carried out one after another, building in a basic limitation of processing speed). With VLSI technology providing almost mainframe computational performance in increasingly smaller packages, arraying a sufficiently large number of microprocessors can provide cost-effective, next-generation supercomputer performance.

Enter the Hypercube

One approach to concurrent computing is the Hypercube. In this configuration, a number of microprocessors are directly linked in an array containing 2^K processor-nodes, with each node connected to its K nearest neighbors. A $K = 3$ configuration is a normal cube, with eight concurrently operating computers. As K values increase, the configurations are nested and represent cubes in higher spatial dimensions, hence the name "hypercube."

Mark I and II

In 1981, the California Institute of Technology began investigating Hypercube architecture by constructing a first generation 64-node Hypercube, using the Intel 8086 16-bit microprocessor. Its demonstrated performance was about eight times that of the DEC VAX 11/780 supermini computer.

JPL became involved in 1983, designing and contructing the Mark II Hypercube, based on an enhanced Mark I design. Four 32-node Mark II machines and one seven dimensional, ►

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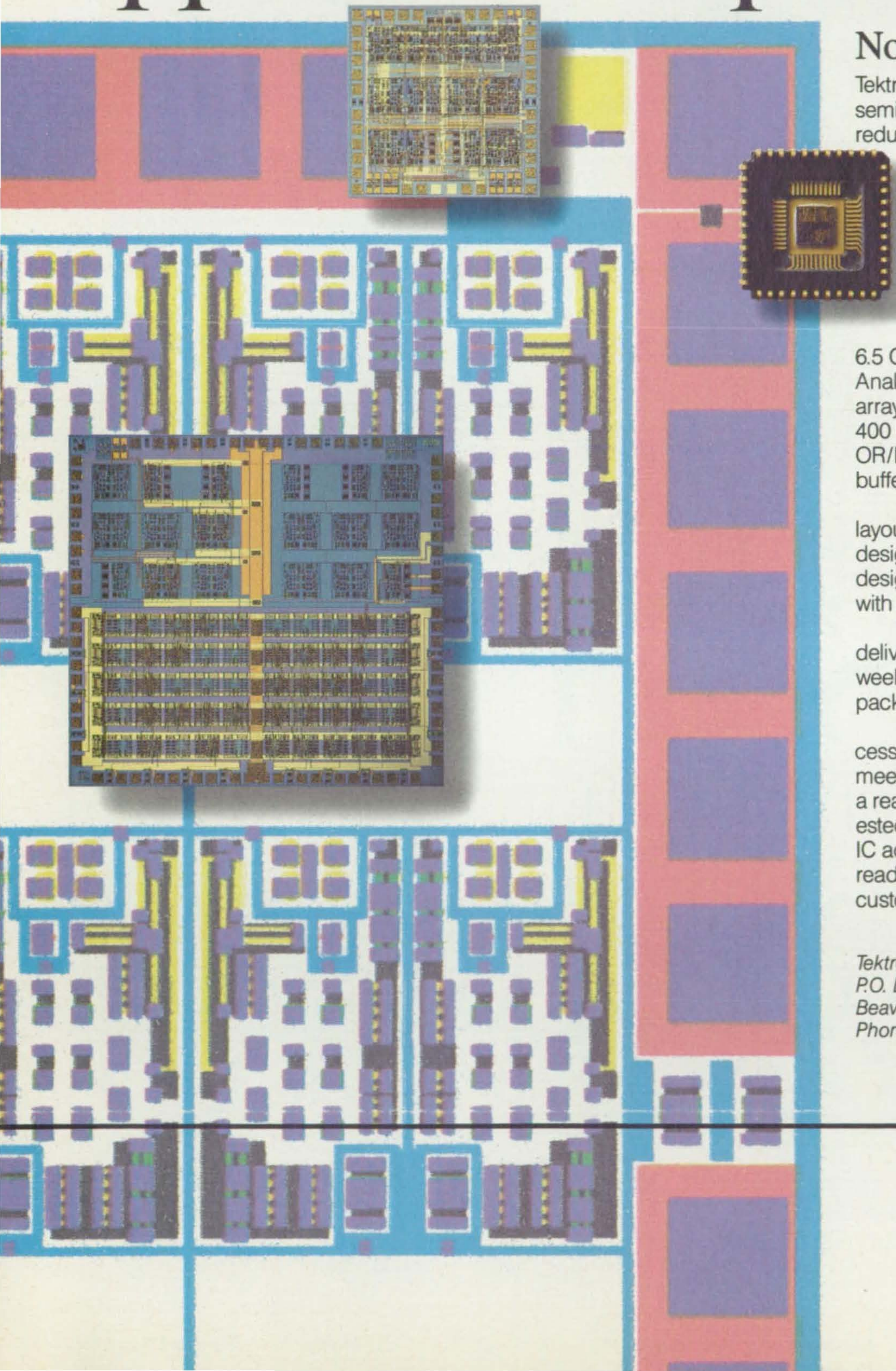

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This 32-node Mark III Hypercube has the computing power of 32 to 64 of the VAX 11/780 minicomputers.

128-node machine were constructed. The 128-node system has the performance of about 25 times the DEC VAX 11/780 supermini computer.

Mark III and IIIe

In 1986 the JPL Hypercube Research Project designed and built the Mark III concurrent computer, based on the Motorola MC68020 32-bit microprocessor. Two four-node systems and two 32-node systems serve as test beds for developing diagnostics and software. Each Mark III node has a performance of between one and two DEC VAX 11/780 computers. Mark IIIe nodes, being designed with Weitek Floating-Point Processor daughter boards, should have a capability of 10 MFlops per node. A concurrent computer assembled from 32 of these enhanced nodes should show performance in the range of a Cray-XMP supercomputer, at about 1/10th the cost. A 256-node system should perform equal to or better than the next generation Cray machines.

More and Better

In the quest for more powerful computers, the Hypercube Research Project participants have a fairly clear view of their crystal ball. Dave Rogstad, Principal Investigator at the Hypercube Project, doesn't see any theoretical design limitations to adding more nodes to a Hypercube architecture. Practical size could become a consideration, however. Says Rogstad, "What's likely to happen in the future is not that we would increase the number of nodes, or even worry about making the nodes physically smaller; what's more likely is that the nodes themselves will be made from much more powerful and faster chips."

Rogstad mentions some of Hypercube's selling points: "The main reason why Hypercube is considered to be more cost effective is that we're using commercial, off-the-shelf microprocessor components. They tend to be a factor of 10 cheaper than the kind of components that goes into making Crays."

Having designed and built powerful Hypercube architectures, Rogstad and others participating in the Hypercube Project turned their attention to proving the utility of their design. A cost effective computer loses its worth if it can't easily be programmed, but Rogstad and his team have proven otherwise. 'We have demonstrated that you can hook up hundreds of microprocessors and realistically and easily program them on intensive computing problems, the kind of problems you buy Crays to attack."

Because scientific and engineering problems and their solutions are often parallel as well as sequential, the distributed processing inherent in Hypercube architectures offers ideal solutions. Using off-the-shelf components, Hypercubes promise supercomputer performance at a fraction of the cost. □

At Kennedy Space Center, launch preparations includ staying aware of weather conditions. The Thunderstorm Weather Forecasting Expert System project will help predict severe events.

Artificial Intelligence:

Rendezvous with NASA

Once the near exclusive domain of academia, Artificial Intelligence (AI) has begun to make its mark in a number of areas in the scientific and business communities. The development of practical AI applications has been slow for decades, but new, powerful and less expensive computers have helped move AI and expert systems from the confines of the laboratory into the real world.

Artificial intelligence generally refers to the use of computers to supplement or replace human reasoning in decision making processes. Dr. Henry Lum of NASA's Ames Research Center explains that "AI is a very broad term; taken literally it tends to create a great deal of confusion about what AI actually is all about. The term 'expert system' is usually substituted when speaking to most audiences."

Artificial Intelligence now gets its share of headlines, but that hasn't always been the case. Only a few years ago, most of us assumed that AI referred to the crossword puzzle entry for a three-toed sloth. Artificial Intelligence sounded like something that football coaches invoked at halftime to rally the troops. Suffice to say that AI had a recognition problem. More importantly, the vocabulary of AI probably kept a large number of potential users at arm's length; AI is a world populated by terms such as first order predicate logic, inference engines and instantiation. Peering into this world, NASA saw the potential for using expert systems to solve difficult problems related to space flight and the development of the Space Station. A sampling of NASA's current expert systems projects reveals that NASA is making a broad commitment to AI.

One of NASA's expert systems projects, dealing with near term precision weather forecasting, seems to have great potential for further increasing safety in commercial airline flights. Other ambitious NASA AI projects involve with expert planning, payload integration, and machine learning.

Expert System Weather Forecasting

Space Shuttle operational weather forecasting at the Kennedy Space Center (KSC) is provided by the U.S. Air Force for the Cape Canaveral Forecast Facility. Forecasters have tours of duty ranging from two to four years. The expertise that they develop in predicting weather at this coast location leaves when their tour of duty ends. Operational forecasting is further complicated by the volume of data available from conventional weather data sources and from numerous specialized instrumentation systems. ►

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While constructing short term weather forecasts it is difficult to handle large volumes of data and determine which data sources are appropriate to use.

In this context, the Thunderstorm Weather Forecasting Expert System (TWFES) project is developing a weather forecasting aid that captures the individual expertise of forecasters, and also provides a tool for weather event anticipation. Art Beller, manager of the TWFES project, expects that "the system is not going to replace the individual forecaster; it's going to assist him by focussing his attention on anticipating certain events and telling him where to look for supporting data." The initial emphasis on thunderstorm prediction is due to the fact that shuttle operations are strongly affected by lightning near the operational areas. Beller explains that "At KSC there's a thunderstorm everyday during the summer. Patterns begin to emerge; if there's a strong sea breeze off the coast, there probably will be no thunderstorms over the Cape; they'll be inland. Prevailing winds from the west give rise to other scenarios. The idea is to have a machine reason from the scenarios and then assist in the weather prediction process."

The system, which is still in the proof-of-concept phase, runs on a Symbolics 3640 and has a hybrid architecture utilizing both Zetalisp and the Automated Reasoning Tool. The prototype will identify and elaborate additional test scenarios, improve the user interface, and finalize the data interfaces. Beller hopes to add winter thunderstorms to the list of scenarios. "They're especially interesting because they usually have lightning, wind, and precipitation—possibly hail—all of which strongly affect shuttle launch operations." Current plans envision moving the TWFES into the operational setting of the Cape Canaveral Forecast Facility in 1988.

Payload Integration and Checkout

The Spacelab and Experiments Division of Payload Operations at the Kennedy Space Center has developed a real time data distribution network for use in the integration and checkout of scientific payloads prior to their launch on the Space Shuttle. The Smart Processing of Real Time Telemetry (SPORT) project merges high speed Symbolic Lisp Processors and personal computers to existing payload checkout equipment via a 10 Mbit/sec local area network. The SPORT system was first used during level IV testing of the ASTRO-1 SPACELAB payload.

The backbone of the SPORT system is a local area network following the IEEE-802.3 network standard known as Ethernet. Payload checkout equipment is attached to the network via network control processors. These processors encapsulate telemetry information into SPORT protocol packets for routing via DARPA's Standard Internet protocol and the Transaction Control Protocols. Network application processors then remove these packets for use by applications programs.

Two classes of machines are used as Network Applications Processors; IBM PC/AT's for slower applications and Symbolic 3670's for high speed applications. The PC's low level interface routines are written in 8086 assembly language and Lattice C, while the high level data analysis portions are coded in Golden Common Lisp. The high speed applications programs are written in Symbolics Common Lisp and the Automated Reasoning Tool from Inference Corporation.

Expert Planning and Scheduling

Science and applications payloads are processed at KSC through a number of steps before the fly as part of an integrated Space Shuttle payload. Individual experiments are received at the Operations and Checkout building in the KSC Industrial Area. Following inspection and preparation

in support areas, payload elements begin an assembly-line-like process that brings them together to form a compatible, functioning payload unit. Each phase of integration—experiment integration and Spacelab integration—results in a progressively more complete, functional flight payload. Planning and scheduling is an important part of this process, and two expert systems are being developed to enhance existing capabilities: the Expert Mission Planning and Replanning Scheduling System (EMPRESS) and the Planning Network (PLANNET). Eventually the systems may be integrated.

Using the same tools and problem-solving heuristics (rules) as a KSC planning and scheduling expert, EMPRESS will construct and maintain mission schedules. EMPRESS, developed by NASA-KSC and the MITRE Corporation of Bedford, MA, will support schedule planning by defining the time, resources, and task requirements associated with processing a Space Shuttle. EMPRESS will also help the planner with unanticipated schedule changes.

The principal objective of PLANNET (developed by McDonnell Douglas Astronautics-KSC with initial support from Georgia Tech's Engineering Experiment Station), was to demonstrate the feasibility and application of expert system technology to the problem of daily or longer term planning and rescheduling activities, including facility and resource utilization. The initial demonstration addressed only a subset of the planning and scheduling activities, but continuing work will expand the prototype system to make it more realistic.

Machine Learning and Control

As part of KSC's Knowledge-Based Automatic Test Equipment (KATE) project, LISP code has been written that automatically infers the structure of simple black-box circuits. After testing the circuit via a commercial real-world interface and building a table of corresponding inputs and outputs, KATE builds a knowledge-base to monitor, diagnose and control the circuit, and draws the circuit diagram on a CRT. This is called "learning from observed performance," and has direct application to the automatic creation of knowledge-bases to control and monitor hardware systems.

To date, the system has been demonstrated on simple digital logic circuits and has been partially implemented for analog circuits. Circuit control has been demonstrated through goal-oriented functions that search the knowledge-base for commands that can be changed to produce a desired output. All possible command combinations are presented as options to the operator to meet his goal. This command technique eliminates the need for low-level canned procedures for component control. The KATE project will attempt to develop a complete automatic testing system for black-box devices. John Jamieson at KSC explains that "the objective is to build a complete controller monitor system that's rooted in knowledge-based concepts. The system would be a sort of embryonic HAL from 2001; it talks, tells you what it's going to do and what it does; it detects anomalous measurements, performs a diagnosis, locates broken parts and finally writes its own list of steps to get around the problem so that a system can return to a working operational configuration."

The projects described above are but a few of NASA's current initiatives in expert systems. Future issues of NASA Tech Briefs will provide updates on these projects and explore other NASA activities related to artificial intelligence. □

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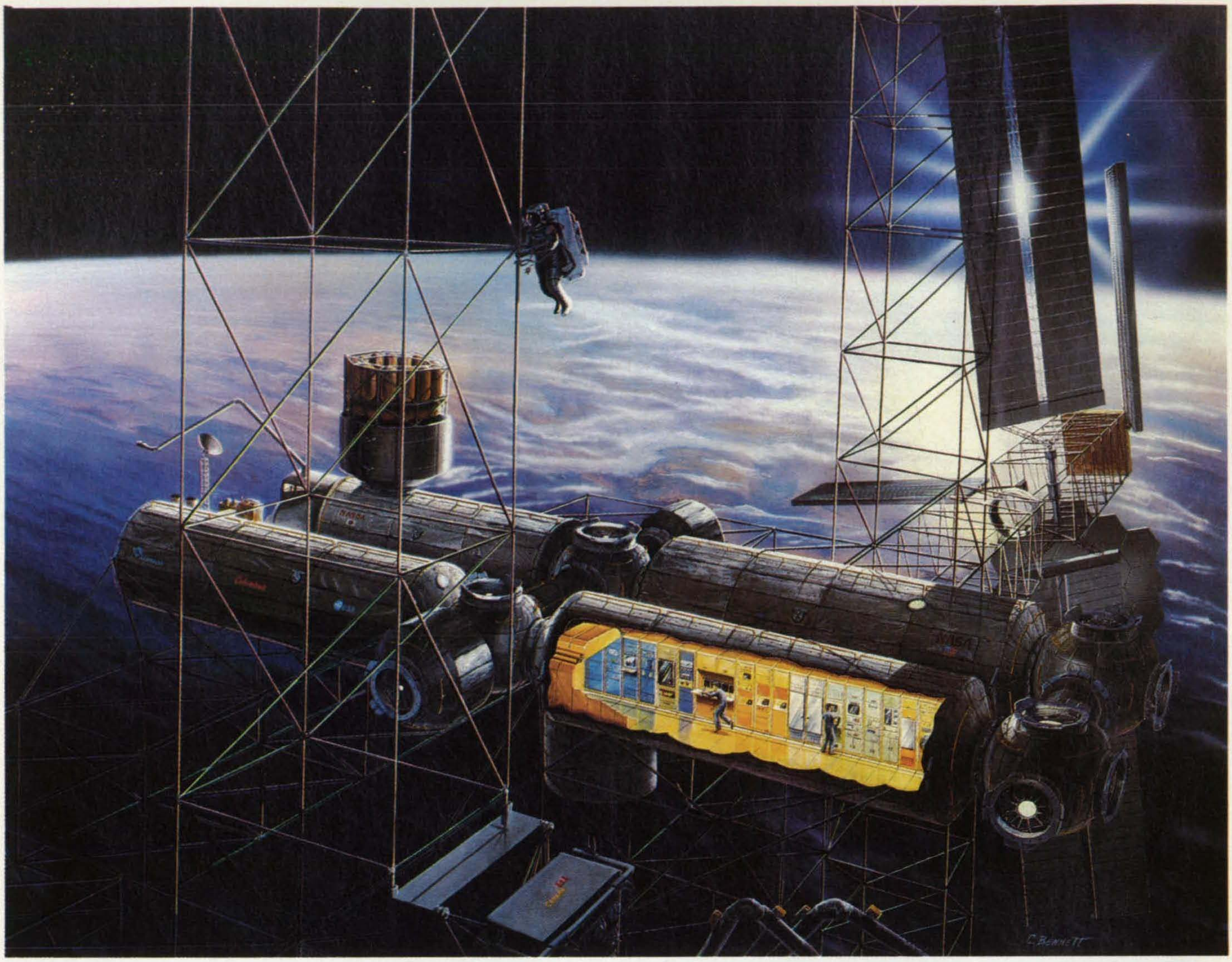


A close-up view of the four pressurized modules that will make up the baseline configuration of the Space Station. The Ada language has been selected for use in all Space Station software.

NASA's Ada Connection

In 1975, the Department of Defense (DoD), seeing the need to consolidate some of the many software languages they were maintaining at that time, sought a multipurpose standard language that could be used for embedded computer systems. A standardized language would bring with it a number of benefits, including that of reducing the costs of designing and implementing compilers and support software, as well as portability.

The "High-Order Language Working Group," garnering worldwide input to the proposed language, devised a series of documents, starting with STRAWMAN and running through STEELMAN, to define the language requirements. The designers took the opportunity to include some of the many advances in programming language technology. Such advances included software development methodology, software management techniques, software modularization and structuring, and software quality.

With an emphasis on reliability and maintainability, the Working Group selected four contractors to produce preliminary designs. These four companies were then pared down to two ►

and given a year to develop their designs. The Cii Honeywell Bull (Louveciennes, France) design was selected by DoD in 1979. It was primarily developed by Dr. Jean Ichbiah, and named Ada.

NASA first became involved with Ada through the Office of Aeronautics and Space Technology, and then through Johnson Space Center, selected in 1983 as one of two federal Beta test sites for DoD's newly-developed compilers.

Ideally suited for the life-cycle of large, complex applications, Ada has been selected for the Space Station. One of Ada's strengths is its support for parallel, fault tolerant program modules--especially important for the Space Station. At the Goddard Space Flight Center (GSFC), several projects are being used to assess Ada's suitability for NASA use and to gain expertise in the language.

GSFC's Mission Operations and Data Systems Directorate

Goddard's Mission Operations and Data Systems Directorate (MO&DSD) is reviewing Ada and its support environments under the guidance of Bob Nelson. Pilot projects are being used to understand Ada's impact on the software development life cycle. These include the Attitude Dynamic Simulator for the Gamma Ray Observatory; the Multi-Satellite Operations Control Center simulator, and the Flight Dynamics Analysis System.

Attitude Dynamic Simulator for Gamma Ray Observatory

Developed concurrently in both Ada and Fortran, the Attitude Dynamic Simulator (ADS) project contrasts the software development process. The ADS models the Gamma Ray Observatory's orientation in its dynamic rotations during torquing and maneuvers. With the software instrumentation process developed by Goddard's Software Engineering Laboratory, several methods are available to measure productivity and the number of changes and errors.

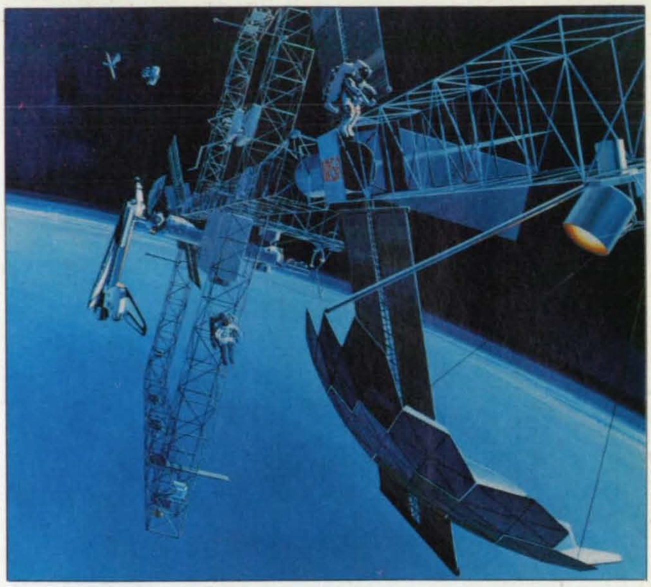
MO&DSD researchers are comparing the Fortran and Ada designs and the time required for their implementation. Says Nelson, "They'll change the specs when the projects are completed to see what happens when the program is modified, how easy modifications are on both the Fortran and the ADA versions. To get an outside perspective, they'll bring in a different person to do those changes."

The ADS project is currently in the implementation phase. In the requirements and the design phases, the Ada domain has taken 10-20% more resources, according to Nelson. He adds, "The key is that the learning cycle is involved; this is a first project."

Other Ada Projects at Goddard

The Flight Dynamics Analysis System project, due for completion in March, 1987, is another way the Goddard team is gaining Ada expertise. The project targets a spacecraft's orbit, determining its orbital location, orientation and velocity. Though the concept changes, the design is kept up to date because Ada's modularity minimizes the extent of any modifications.

The Multi-Satellite Operations Control Center (MSOCC) simulates the functions of a mission control center, processing simulated telemetry from a satellite and sending it commands. A small team for the MSOCC easily generated 10,000 lines of code, and showed high productivity figures in the latter stages of the program's development, according to Nelson. ►



In the foreground of this artist's concept of the Space Station is the solar dynamic power system. Solar array panels will also be used to generate electricity for the station. Pressurized modules for the crewmembers are shown in the center of the photo.

Summarizing his Ada results, Nelson mentions "With the large, fully instrumented ADS project, we can show what the characteristics are and validate for project managers who have a very conservative nature. There is a reduced level of risk; there are a lot of benefits to using Ada in the long term. A lot of the benefit of Ada comes when other projects can reuse some of the software."

He adds, "A lot of the experience we're gaining from the smaller projects is helping us make decisions and plan for future Ada uses. One of the things I'm involved in is the Software Support Environment, a definition and development for the Space Station."

Ada and the Space Station

Ada has been selected as the language for the Space Station Software Support Environment (SSE). An extensive software engineering environment such as Space Station includes a large number of tools; software development is much more than just the compiler—it includes requirements analysis, design tools and testing tools. Ada supports these well. According to Nelson, "Because the Space Station is expected to perform over a 20-30 year life cycle, we have to develop and acquire a sophisticated environment to support it." Ted Humphrey, an Aerospace Technologist in the Data Management Section at Johnson Space Center, says that "Development in both ground and on-board software will be written in Ada as long as a compiler is available." "Exceptions to Ada will be allowed, but only when there is previously produced software that can be picked up and used again or for features that Ada doesn't support well," mentions Nelson.

He adds, "We would like to minimize the amount of hardware-peculiar software so we can move to new hardware technology as it evolves. Tests here at Goddard prove Ada's easy portability from one machine to another."

As pilot programs at Goddard increasingly prove Ada's suitability to NASA and other aerospace applications, an intensive Ada instruction program is underway—and with encouraging results. Nelson is optimistic about Ada's future: "Project Managers ask me, as they're in the procurement phase: 'Do you think Ada is ready?' I think it is; we've shown that in the last year and a half through our different pilot projects. So I think we're at the threshold of selecting Ada for other projects." □

COSMIC:

NASA's Software Treasurehouse

Generating thousands of lines of code each year, NASA's programmers toil at their terminals, developing the most basic and most essential aspect of any modern automated system: the programs that enable computers to work.

Recognizing that the fruits of this effort should be disseminated as widely as possible, NASA established the Computer Software and Management Information Center (COSMIC) in 1966 as a contract between the University of Georgia and Marshall Space Flight Center. Its purpose: to distribute NASA-developed software to industry. COSMIC's scope extended NASA-wide in 1967, with the University of Georgia continuing as the operator.

As COSMIC celebrates its 20th anniversary year, its library of available, applicable programs is 1200 strong, with approximately 20 new ones added each month. Potential customers can purchase a catalog, select programs that seem appropriate, and request documentation to make a final determination. Software, purchased separately on either magnetic tape or floppy disk format, includes source code.

NASA-subsidized, COSMIC's state-of-the art programs are available at a fraction of their development cost. Most programs in COSMIC's library cost $1000 or less, with some as low as $25.

Purchasing a COSMIC program isn't a single-event phenomenon; the Center's staff helps clients adapt programs to their own hardware. Should a software bug arise, COSMIC's experts will track it down, or contact the program's author for his input.

NASA programs submitted for the library are reviewed by COSMIC's staff and compiled at the University of Georgia, often on the same type of equipment they were developed on. Documentation is reviewed for completeness, and if the software has application outside of its original purpose, it is added to the library.

Potential COSMIC programs should be submitted to the Technology Utilization Officer (TUO) at the appropriate NASA Center, who will forward them to COSMIC. According to John A. Gibson, COSMIC's Director, "We are looking for generalized programs that have as broad an application base as possible."

NASA employees or contractors interested in COSMIC's programs should contact their TUO. COSMIC's address is given on page 42.

Golden Oldies

Because software becomes obsolete with time, COSMIC housecleans every two to three years, removing programs that haven't been requested for five years. "Golden Oldies," programs that have kept their relevance over time, are described here:

SPAR—Structural Performance Analysis and Redesign (Engineering Information Systems, Inc.) SPAR is a system of computer programs designed to perform stress, buckiing, vibration, and thermal analysis of large linear finite element structural models. LAR-12213; LAR-12370; LAR-12371; LAR-12542; MFS-23944
Circle 1 on the TSP Request Card.

STAGSC-1—Structural Analysis of General Shells (Lockheed Missiles & Space Co.) The STAGSC-1 computer program is intended primarily for the practical engineering analysis of thin shell structures. These shell structures may contain a number of separate shell branches or segments connected to one another along their boundaries. HQN-10960; HQN-10962; HQN-10967
Circle 2 on the TSP Request Card.

PASCO—Structural Panel Analysis and Sizing-Code (NASA Langley Research Center). PASCO was developed for the buckling and vibration analysis and sizing of prismatic structures having an arbitrary cross section. PASCO is primarily intended for analyzing and sizing stiffened panels made of laminated orthotropic materials and is of particular value in analyzing and sizing filamentary composite structures. LAR-13004; LAR-13164
Circle 3 on the TSP Request Card.

PAFAC—Plastic and Failure Analysis of Composites (NASA Langley Research Center). A three-dimensional finite-element computer program called PAFAC has been developed for the elastic-plastic analysis of fiber-reinforced composite materials and structures. LAR-13183
Circle 4 on the TSP Request Card.

FLAGRO4—Advanced Crack Propagation Predictive Analysis (Rockwell International Corp.). FLAGRO4 was developed as an aid in predicting the growth of pre-existing flaws and cracks in structural components. MSC-18718; MSC-18721
Circle 5 on the TSP Request Card.

SINDA—Systems Improved Numerical Differencing Analyzer with Sinflo (TRW Systems Group). SINDA is a software system developed for solving physical problems governed by diffusion-type equations which can be modeled by lumped parameter representation. MSC-13805; MSC-18597; MSC-20891
Circle 6 on the TSP Request Card.

TRASYS II—Thermal Radiation Analysis System (Lyndon B. Johnson Space Center). TRASYS II is a computer software system with generalized capability to solve the radiation related aspects of thermal analysis problems. MSC-20448; MSC-21030
Circle 7 on the TSP Request Card.

General Thermal Analyzer (Rockwell International Corp.). The General Thermal Analyzer program solves transient and steady-state thermal problems using desk-top computers. MSC-20702; MSC-21140
Circle 8 on the TSP Request Card.

LOHARP—Lockheed Orbital Heat Rate Package (Lockheed Missiles & Space Co.). The LOHARP package was developed to calculate the temperature distribution of an orbiting space craft. MFS-23980
Circle 9 on the TSP Request Card.

DISCOS—Dynamic Interaction Simulation of Controls and Structures (NASA Goddard Space Flight Center). The DISCOS program was developed for the dynamic simulation and stability analysis of passive and actively controlled spacecraft. GSC-12422; GSC-12810
Circle 10 on the TSP Request Card.

ORACLS—Optimal Regulator Algorithms for the Control of Linear Systems (NASA Langley Research Center). This control theory design package was developed to aid in the design of controllers and optimal filters for systems which can be modeled by linear, time-in-variant differential and difference equations. GSC-13067; LAR-12313; LAR-12953
Circle 11 on the TSP Request Card.

NBOD2—Program to Derive and Solve Equations of Motion for Coupled N-Body Systems (NASA Goddard Space Flight Center). The NBOD2 computer program was developed to aid in the analysis of spacecraft attitude dynamics. NBOD2 is a very general program that may be applied to a large class of problems involving coupled N-body systems. GSC-12846
Circle 12 on the TSP Request Card.

IAC—Integrated Analysis Capability (NASA Goddard Space Flight Center). The objective of the Integrated Analysis Capability (IAC) systems is to provide a highly effective, interactive analysis tool for the integrated design of large structures. IAC was developed to interface programs from the fields of structures, thermodynamics, controls, and system dynamics with an executive system and a database to yield a highly effecient multi-disciplinary system. GSC-12992; GSC-12994
Circle 13 on the TSP Request Card.

Golden Oldies

SHABERTH—Thermal Performance of a Shaft Bearing System (SKF Industries, Inc.). The computer program SHABERTH was developed to predict the steady state and transient thermal performance of a multi-bearing shaft system operating with either wet or dry friction. LEW-12761
Circle 17 on the TSP Request Card.

QSONIC—Full Potential Transonic, Quasi-Three Dimensional Flow through a Rotating Turbomachinery Blade Row (NASA Lewis Research Center). The QSONIC computer program has been developed for calculating the full potential, transonic quasi-three-dimensional flow through a rotating turbomachinery blade row. LEW-13832
Circle 19 on the TSP Request Card.

PANAIR—Predicting Subsonic or Supersonic Linear Potential Flows about Arbitrary Configurations Using a Higher Order Panel Method (Boeing Computer Services Co.). PANAIR (an abbreviation for "Panel Aerodynamics") is a state-of-the-art system of computer programs developed to predict inviscid subsonic and supersonic flows about an arbitrary configuration by means of a higher order panel method. ARC-11398; ARC-11499
Circle 20 on the TSP Request Card.

INCA—Interactive Controls Analysis (NASA Goddard Space Flight Center). The INCA program was developed to provide a user friendly environment for the design and analysis of linear control systems, primarily feedback control systems. GSC-12998
Circle 14 on the TSP Request Card.

TSONIC—Transonic Velocities on a Blade-to-Blade Stream Surface of a Turbomachine (NASA Lewis Research Center). This program obtains a transonic flow solution on a blade-to-blade surface between blades of a turbomachine. The flow must be essentially subsonic, but there may be locally supersonic flow. LEW-10977
Circle 15 on the TSP Request Card.

MERIDL—Velocities and Streamlines on the Hub-Shroud Midchannel Stream Surface of an Axial, Radial, or Mixed Flow Turbomachine or Annular Duct (NASA Lewis Research Center). This computer program was developed for calculating the subsonic or transonic flow on the hub-shroud mid-channel stream surface of a single blade row of a turbomachine. LEW-12966;
Circle 16 on the TSP Request Card.

Three Dimensional Potential Flow Program with Geometry Package for Generation of Input Data (McDonnell Douglas Corp.). A computer program for calculating viscous effects on the lifts and pressure distributions of arbitrary three-dimensional configurations has been developed by combining a panel method, which calculates potential flow about arbitrary three-dimesional lifting configurations, with a two-dimensional boundary-layer method which is used in a strip-theory sense. LAR-12623
Circle 21 on the TSP Request Card.

GRAPE—Two Dimensional Grids About Airfoils and Other Shapes by the Use of Poisson's Equation (NASA Ames Research Center) The GRAPE computer program was developed to incorporate a method for generating two-dimensional finite-difference grids about airfoils and other shapes by the use of the Poisson differential equation. ARC-11379
Circle 22 on the TSP Request Card.

PROFILE—The Eppler Program for the Design and Analysis of Low-Speed Airfoils (Stuttgart Univ.). The PROFILE computer program was developed as an aid in the design and analysis of low-speed airfoils. LAR-12727
Circle 23 on the TSP Request Card.

NCOREL—Nonconical Relaxation for Three-Dimensional Nonlinear Supersonic Potential Flow (Grumman Aerospace Corp.). The NCOREL program employs a new computational technique for the prediction of inviscid, nonlinear supersonic aerodynamics. LAR-13346
Circle 24 on the TSP Request Card.

Hidden Line Computer Code (NASA Dryden Flight Research Center). The requirement for computer-generated perspective projections of three-dimensional objects by way of line drawings has escalated significantly in recent years. Mathematician David Hedgley of NASA's Dryden Flight Research Facility has developed a new efficient solution to the hidden line problem, and has incorporated it into a Hidden Line Computer Code. ARC-11446
Circle 25 on the TSP Request Card.

SHADE—Shaded Color Picture Generation of Computer Defined Arbitrary Shapes (NASA Ames Research Center) The SHADE computer program was developed to provide for the generation of realistic shaded color pictures from computer defined arbitrary shapes. ARC-11496
Circle 26 on the TSP Request Card.

LONGLIB—A Graphics Library for the Dec Vax Computer (Cal Tech/Jet Propulsion Lab.). This library is a set of subroutines designed for vector plotting to CRT's and dot matrix printers. NPO-16666
Circle 27 on the TSP Request Card.

ELAS—Earth Resources Laboratory Applications Software (NASA Earth Resources Laboratory) ELAS software is a geobased information system designed for analyzing and processing digital imagery data. ERL-10016; ERL-10017; ERL-10018
Circle 28 on the TSP Request Card.

Computer Programs

COSMIC: Transferring NASA Software

COSMIC, NASA's Computer Software Management and Information Center, is the one central office established to distribute software that is developed with NASA funding. COSMIC's role as part of NASA's Technology Utilization Network is to ensure that NASA's advanced software technology is made available to industry, other government agencies, and academic institutions.

Because NASA's software development efforts are dynamic and ongoing, new programs and updates to programs are added to COSMIC's inventory on a regular basis. *Tech Briefs* will continue to report information on new programs. In addition, the 1986 edition of the *COSMIC Software Catalog* is available with descriptions and ordering information for available software. Several new programs for control systems/robotics, expert systems, thermal analysis, turbomachinery design, structural analysis, and computer graphics are offered.

For additional information on any programs described in this issue of *Tech Briefs*, circle the appropriate number on the TSP card at the back of the publication. If you don't find a program in this issue that meets your needs, you can call COSMIC directly at (404) 542-3265 and request a review of programs in your area of interest. There is no charge for this information review.

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Computer Programs

These programs may be obtained at a very reasonable cost from COSMIC, a facility sponsored by NASA to provide tested and reliable software to the public. For information on program price, size and availability, circle the reference number on the TSP and COSMIC Request Card in this issue.

Electronic Components & Circuits

Grid-Optimization Program for Photovoltaic Cells

Power loss due to electrical resistance and shadowing is minimized.

The CELLOPT program was developed to assist in designing the grid pattern of current-conducting material on a photovoltaic cell. CELLOPT analyzes the parasitic resistance losses and shadow loss associated with the metallized grid pattern on both round and rectangular solar cells. Although CELLOPT can perform sensitivity studies, it is used primarily to optimize the grid design in terms of the bus bar and grid lines by minimizing the power loss.

The collecting bus bar may be of the same metal and thickness as the grid lines or it may be "strapped", i.e., thicker and of a different material. The bus bar is orthogonal to the grid lines. A round cell may have one or two bus bars, and a rectangular or square cell may have any number.

The power-loss analysis in CELLOPT calculates the contact resistance; shadow loss; and resistances due to the photovoltaic sheet, grid lines, and bus line. The optimization method follows a modified Newton-Raphson procedure. To optimize the grid design the designer may choose any two or all three of the following variables: bus-bar width, grid-line width, and grid-line spacing.

The user must supply such cell electrical parameters as the maximum voltage and current density, the resistivity of the metal and semiconductor sheet materials, and the locations of the bus bars. CELLOPT calculates the minimum total power loss for a given set of characteristics and tabulates such information as the component power losses, volumes, and shadows.

CELLOPT is written in APL for interactive execution and has been implemented on a UNIVAC 1100-series computer. This program was developed in 1985.

This program was written by Ronald E. Daniel and Thomas S. Lee of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 146 on the TSP Request Card.*
NPO-16804

Mechanics

Aerodynamic Prediction for Supersonic Canard-Tail Missiles

Pressure loads and moments are predicted.

The LRCDM2 computer program was developed to calculate the pressure distribution at points on the surfaces of a complete supersonic missile. The missile can comprise up to two finned sections attached to an axisymmetric body of circular cross section. LRCDM2 includes the effects of vortex shedding due to the forebody and forward fins, providing more accurate rolling moments.

LRCDM2 is applicable for mach numbers up to 6 and angles of attack up to 25°. The predicted aerodynamic loads are in good agreement with actual measurements of flow characteristics. Experimental results are described for a rectangular wing, a delta wing, triform tail fins, and a canard-controlled configuration.

The detailed static aerodynamic-loading analysis in LRCDM2 is based on supersonic paneling and line-singularity methods coupled with vortex-tracking theory. Two-dimensional nonlinear Carlson shock-expansion and supersonic-strip theories are combined with three-dimensional linear analysis to modify interference shells on the missile body. The vortex-trajectory calculations incorporate nose-vortex shedding and fin leading- and/or side-edge vorticity characteristics. An optional afterbody vortex-shedding program included in this package can be used alone or in conjunction with LRCDM2 to examine the effects of afterbody vorticity on the tail-fin pressure distribution.

The input to LRCDM2 includes the size and shape of the missile, modeling options, the body orientation, and the flow conditions. The output from the program details the pressure distribution, aerodynamic loads, and moments. It also shows the cumulative effects of fin and body vortexes at control points across the body.

LRCDM2 is written in FORTRAN IV for batch execution and has been implemented on a CDC Cyber 170-series computer operating under NOS with a central-memory requirement of approximately 270K (octal) of 60-bit words. This program was developed in 1985.

This program was written by Marnix F. E. Dillenius of Nielsen Engineering and Research, Inc. for **Langley Research Center**. *For further information Circle 142 on the TSP Request Card.*
LAR-13527

Orbital-Lifetime Program

The long-term effects of small perturbations are predicted.

The Orbital Lifetime Program (OL) analyzes the long-term motion of Earth-orbiting spacecraft at altitudes of up to 2,500 km. It models perturbations to the orbit caused by solar-radiation pressure, atmospheric drag, and gravitational effects of the Sun, the Moon, and the oblate Earth. OL can be used to perdict the orbital lifetime and decay rate of a satellite.

The atmospheric-density models used in OL are the U.S. Standard Atmosphere for altitudes below 90 km and the Jacchia model for altitudes above 90 km. The Jacchia model requires the solar flux and geomagnetic index for the date of the orbit. An input file containing these values for 1984 to 1998 is supplied with the OL package. The solar-radiation-pressure calculations in OL will predict the amount of time a spacecraft is subjected to the Earth's shadow. The input to OL includes space-

craft physical characteristics, initial orbit parameters, and the launch date and time. OL calculates time histories of the orbital elements, total lifetimes, and decay rates. A spacecraft is considered "down" at an altitude of 64 km. OL also generates a file of plot data that can be put into a user-supplier graphics program for lifetime plots of altitude against time.

OL is written in FORTRAN 77 for interactive or batch execution and has been implemented on a DEC VAX-series computer operating under VMS. This program was developed in 1985.

This program was written by Lynne H. Orr of **Langley Research Center**. *For further information, Circle 143 on the TSP Request Card.*
LAR-13557

Machinery

Advanced Rotordynamic Nonlinear Transient Simulation

Loads and displacements are predicted for a variety of rotating machinery.

The advanced rotordynamic nonlinear transient-simulation program, TRANSIM, was developed to predict the response of high-performance rotating machinery to a variety of forcing functions. The program works by modal superposition of rotor and casing subsystems (or two simultaneously rotating subsystems). The transient response of the system is calculated by numerical integration of the equations of motion, performed in modal coordinates. The resulting data are transformed back into physical coordinates as required to determine the user-requested loads and accelerations as a function of time. TRANSIM has been used to analyze the Space Shuttle main engine high-pressure fuel turbopump.

TRANSIM allows the user to couple the rotor to the casing with linear and nonlinear interconnecting elements. Linear connectors between the two subsystems can account for forces resulting from intergroup stiffness, damping, and effective inertia, as well as forces from rotating and fixed effective inertia at a specified location. Stiffness, damping, and effective inertia forces can also be applied within (i.e., intragroup) either subsystem.

Nonlinearities in the system are confined to intergroup elements. These elements permit simulations of such rotordynamic phenomena as bearing deadband, tangential rubbing (Coulomb), and piecewise-linear spring rates. Connector parameters can be made dependent on speed. TRANSIM simulates floating-ring seals with Coulomb damping, including the effects of gyroscopic moments in the rotating subsystem.

Forcing functions available for system excitation include rotating unbalance, speed-dependent sideloads between the rotor and casing, and a variable-frequency sinusoidal force applied to the casing. A stability-assessment algorithm determines the logarithmic decrement (or equivalent critical damping ratio) of the most predominant modes via a multifrequency decay-rate analysis.

TRANSIM requires uncoupled linear modal representations of the rotor and casing as inputs. The output from TRANSIM consists of printed and plotted root-mean-square time histories of any linear and nonlinear intergroup elements, relative defections, and casing accelerations, as well as fast Fourier transforms of these responses. Intergroup-element-load time-history and orbit plots for any specified time slice can be made, as well as a complete time-history plot of the displacement of a floating-ring seal. Simplified vector analyses are performed on the intergroup loads to determine fixed and alternating components and fixed load or displacement angles.

TRANSIM is written in FORTRAN 77 for batch execution and has been implemented on a CDC CYBER 800-series computer operating under NOS with a central-memory requirement of approximately 222K (octal) of 60-bit words. This program requires the IMSL and DISSPLA commercial software libraries and is coded to support an SC4020 plotter for graphics output. TRANSIM was developed in 1985.

This program was written by David G. Becht of Rockwell International Corp. for **Marshall Space Flight Center**. *For further information, Circle 107 on the TSP Request Card.*
MFS-19939

Mathematics and Information Sciences

Program for Experimentation With Expert Systems

Deductions are performed according to data and to rules set by the user.

CERBERUS is a forward-chaining, knowledge-based system program useful for experimentation with expert systems. The inference-engine mechanism in CERBERUS performs deductions accord-

ing to a user-supplied rule set. Information is stored in an intermediate area, and the user is interrogated only when no applicable data are found in storage. Each assertion posed by CERBERUS can be answered with a certainty ranging from 0 to 100 percent. The rule processor stops investigating (or "firing") applicable rules when a goal reaches a certainty of 95 percent or higher.

CERBERUS is capable of operating for a wide variety of domains. Sample rule files are included for animal identification, pixel classification in image processing, and rudimentary car repair for the novice mechanic. The user supplies a set of end goals or actions (for example; car needs oil; chemical is sulfur), which are obtained by a combination of assertions (engine runs hot, and water level is high; sample is yellow, burns, and is a nonmetallic solid). The system complexity is decided by the user's rule file, since each assertion may be composed of previous assertions (water level is high when engine is off; choke is wedged open).

The CERBERUS rule file is created by the user with an ordinary text editor in free format. The rule file may contain comments, equations, and rules. A rule consists of assertions (possibly linked by operands), a conclusion clause, and a strength factor. The strength factor is the percentage of the final conclusion to be determined by that particular rule. The initial rule file can be analyzed by CERBERUS to give a breakdown of vocabulary, and tables of assertions, equations, and rules: CERBERUS provides options for tracing the network of rules as the program operates, logging all user replies, and recounting the rules used to reach a given conclusion on an "as-fired" basis.

CERBERUS is written in FORTRAN 77 for interactive execution and has been implemented on a DEC VAX-series computer operating under VMS. The program is general in structure and should be transportable to other systems. CERBERUS was developed in 1985.

This program was written by Steven W. Engle of Informatics General Corp. for **Ames Research Center**. *For further information, Circle 78 on the TSP Request Card. ARC-11688*

Listing Relationships Among Subroutines

Hierarchical charts of subprograms are generated.

The HIERARCHY program is a tool that assists users in obtaining information about the relationships among subroutines in a computer program. HIERARCHY uses the FORTRAN source code and load maps generated by the Cray FORTRAN compiler to generate tables of attributes for each module, including input and output operations, entry points, arguments, and NAMELIST's. These tables also describe the relationships of modules to modules and of modules to COMMON's.

The COMMON's, both labeled and unlabeled, are checked for consistent length. HIERARCHY will note the frequency distribution of calls to other modules and library or service routines. The program generates an optional hierarchical chart of subprograms to show how they relate to the main program. HIERARCHY can accommodate programs of up to 50 calls deep.

HIERARCHY is written in FORTRAN 77 for batch execution and has been implemented on a Cray X-MP computer operating under COS with a central-memory requirement of approximately 133K (octal) words. This program was developed in 1984.

This program was written by Clayton Guest of Informatics General Corp. for **Ames Research Center**. *For further information, Circle 79 on the TSP Request Card. ARC-11609*

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Dig

tal Fly-By-Wire

A Case of Bidirectional Technology Transfer

By James E. Tomayko

One of the prime benefits of the space program is the transfer of technology to such areas as materials science, medicine, and electronics. This often has been a one-way street. However, one NASA research program not only resulted in adapting space flight techniques to the realm of aeronautics, but also to using an advanced form of the aeronautical technique to prove a concept incorporated in the Space Shuttle. This double technology transfer was accomplished during the Digital Fly-by-Wire Program conducted at the Dryden Flight Research Center in Edwards, California, during 1970-1978. Phase One used Apollo hardware to establish fly-by-wire technology, and Phase II acted in part as a testbed for Space Shuttle software.

The Concept of Digital Fly-by-Wire

Digital fly-by-wire is a method of controlling an aircraft electronically rather than mechanically. From the Wright brothers until recently, the dominant way to move an airplane's control surfaces (elevators, ailerons, rudder, flaps) has been with mechanical linkages from the cockpit control devices. For example, a pilot pulling back on his control stick moves a cable or rod attached to the base of the stick and connected to the elevators, usually through a hydraulic system that enhances the force of the pilot's pull, enabling him to easily move the control surface. In a digital system, the mechanical path to the control surface is broken. Devices are inserted to convert stick and rudder pedal manipulations to voltages. These voltages are measured and the data are entered into a set of control laws programmed into a digital computer. The computer outputs the appropriate commands to actuators that then control the force applied through the hydraulic system. With a sufficiently sophisticated set of control laws, the airplane can be made more "flyable."

The concept of digital control was applied in the manned space program. The only method of controlling the Mercury, Gemini, and Apollo manned spacecraft was by the use of rockets, both small thrusters for attitude control and minor orbit changes and large engines for major corrections to the flight path. The Mercury capsules had neither a digital computer nor an orbital maneuvering system, just attitude control jets that could be fired either by the astronaut or the ground controllers. The Gemini spacecraft contained a computer used as a back-up for the launch-vehicle guidance computer and for rendevous and reentry operations. Gemini had some lifting capability and could be maneuvered during descent within a "footprint" some 400 miles long and a few dozen miles wide by controlling its attitude.

However, it was the Apollo program that most extensively used fly-by-wire techniques. The Apollo missions included a considerable amount of automatic attitude control, and that was accomplished using the computer to fire thrusters. The computer also calculated and conducted main engine burns for course corrections, orbit changes, and the like. The ►

Fly-by-wire techniques of the future are simulated in the Ames Proximity Operations (Prox-Ops) Space Station mockup as an operator transfers an Orbiting Maneuverable Vehicle (OMV) to the Space Shuttle. Pioneering fly-by-wire technology originated with the Space Shuttle, shown here on its Boeing 747 carrier plane, and its partner, the Digital Fly-by-Wire F-8C.

astronauts could control the spacecraft only through this digital system.

Origins of the Digital Fly-by-Wire Program

As the Apollo program scored its greatest successes in late 1968 and 1969, a group of engineers at NASA's Dryden Flight Research Center considered the use of digital control techniques for aircraft. There appeared to be obvious advantages to testing such a system, as digital fly-by-wire promised to revolutionize the design of high-performance aircraft such as the F-16 and the current X-29 with forward-swept wings. One advantage for such aircraft is in more precise maneuver control, another is increased combat survivability due to the presence of redundant systems. Large commercial aircraft could benefit because better control would mean a smoother ride for passengers and cargo. Also, weight and space savings could result. But before such systems were applied to either military or commercial flight, they had to have proven reliability. The success of the manned space program indicated that digital systems could be made reliable, but their use in controlling aircraft remained a problem to be solved.

The key consideration in a digital system is the type and capabilities of the computer to be used in it. Due to reliability considerations, the Flight Research Center engineers wanted to have a redundant set of computers. However, the cost of developing and man-rating a new computer for this program was high. Therefore, the already-existing Apollo guidance computer with its inertial measurement unit and related devices became the digital system for the program. There was a disadvantage to using the Apollo system; it was developed exclusively for use on the Apollo spacecraft, with no thought of other applications. This meant that some significant adaptations needed to be made before it could work in an aircraft. Several advantages outweighed this consideration:

—The Apollo computer was so carefully constructed, with such attention to piece-part screening and testing, that it could be used confidently as a simplex system, with no redundancy, just as in the Apollo spacecraft.

—Several Apollo missions were cancelled, making surplus (and already paid for!) equipment available.

—The project could press on immediately, due to existing Apollo contracts with Delco (digital hardware), the Charles Stark Draper Laboratory of the Massachusetts Institute of Technology (software), and Sperry (analog back-up devices).

—Software development and support facilities were in place. Software, as learned during the Apollo experience, is often the pacing item in a project involving computers. The existence of tools to assist in software development was an important factor in the program's rapid implementation and success.

Thus equipped, the conversion process began for what the Dryden engineers claim was the world's first aircraft with "full authority" digital fly-by-wire.

From Mechanical to Digital: The Metamorphosis of an Airplane

The airplane chosen for fly-by-wire demonstrations was the Vought F-8 Crusader. NASA acquired several of these aircraft for research purposes. One of NASA's F-8s became the test aircraft for supercritical wing research. Two others were assigned to the fly-by-wire program. Dryden engineers removed the portions of the wing of an F-8A that folded for carrier storage and modified it further into a test-bed. Permanently grounded, this "Iron Bird" made possible the testing of the hardware and software associated with the program before clearing it for flight. A pilot could sit in the Iron Bird simulator and move control surfaces driven by equipment identical to the flight version.

One advantage is more precise maneuver control.

The first step in transforming the aircraft to a digital-controlled vehicle was breaking the chain of mechanical linkages. To provide electrical inputs to the computer, linear variable differential transformers (LVDTs) were installed to convert the mechanical stick and rudder pedal movements. Engineers installed LVDTs for pitch on the right side of the aircraft aft of the cockpit. Roll LVDTs were put on the left side of the airplane. Due to rudder cable stretching, the yaw transformers were at the base of the tail. When the pilot moved the stick or rudder, the portion of the mechanical cable that remained between the control device and its LDVT also moved, affecting the voltage output from the transducer. The voltages were input to an interface unit that converted them to a format understandable by the software.

The next part of the conversion process was installing the surplus Apollo hardware. The Apollo guidance computer was a fixed-point machine using 16-bit words that had a cycle time of 11.7 microseconds, slower than most personal computers today. It came with 36k words of mixed memory and 2k words of erasable memory.

The Apollo spacecraft flew with two computers, one in the command module and one in the lunar excursion module. Their hardware was identical, but the software was necessarily different. The astronauts communicated with the computer through a display and keyboard unit (DSKY) which contained a keyboard for entering numbers and commands, and five-digit displays for data as well as warning lights.

The F-8 carried a DSKY in the left gun bay, where a ground crewman could activate the flight control program before takeoff. The DSKY was a crude data entry and retrieval system, even for the 1960s, compared to the simplest home computer of the 1980s, but Dryden engineers considered it "pretty good compared to what we had later" in Phase II. This was because the DSKY allowed specific parameters stored in the erasable memory to be changed between flights. The Phase II software came from Draper on tape, with no interface capable of changing it.

The software structure was quite similar to that used in Apollo. The programs were divided into systems and applications programs. Systems programs included the Executive, which essentially controlled the running of the other programs; Restart, which provided a graceful means of beginning the program cycle again after a hardware or software failure; and Service, which did some internal testing and other tasks. Flight control was the primary purpose of the applications programs. Draper took the system software directly from a load prepared for the Apollo 14 flight, making it possible for the developers to concentrate on the applications programs.

Changing the actuator's function in the hydraulic system was another modification to the F-8. Signals from the computer would travel through the interface unit and then to the actuators. Each control surface has secondary electro-hydraulic actuators driving a metering valve in the primary hydraulic power actuator. The secondary actuators have redundant servo valves. In the Phase I program, three valves were present to move each hydraulic system. One was prime, and ►

did the actual work; the other two were back-up. In Phase II, all servos drive the hydraulics together.

This set of components, the LVDTs, computer and initial measurement unit (IMU), software, interface unit, and actuators, complete the transition from a mechanical control system to a digital fly-by-wire system. However, a back-up system had to be provided. To prove the feasibility of fly-by-wire beyond question, the aircraft could not carry a mechanical control system of any sort. Because the electrical equipment was already in the design, an analog electronic back-up using a triply-redundant system was installed. Faults detected in the primary control system caused a switchover to the backup. Examples of such faults are a parity failure in the computer, software entering into an endless loop, an attempt to read data in a part of memory that contained no data, and others detectable by the primary system's hardware or software. A restart or complete switchover would occur depending on the fault's severity or repetition. In all Phase I and Phase II flights, no automatic switchovers ever occurred. The engineers tested the back-ups by having the pilot manually change over to the analog system during several flights.

The Phase I Flight Program

Preparation for the Phase I Flight Program began with testing the digital equipment and its software on the ground. Those tests demonstrated some ways in which the concepts of the control laws needed changes before flight. For example, in early hardware tests, engineers used a hand controller from the lunar module in place of a stick. This was only a matter of convenience, even though it was known that the stick would be used later. This masked a problem that showed up in the Iron Bird when a real stick was used. The difficulty was "coarse quantization" of the inputs by the computer when the stick was moved. The minumum step size for signals created by the software caused commands to the actuators in response to pilot movements to be sent in too-short increments. When this happened, the entire simulator would shake violently, with a frightening noise level.

Despite the racket, the anomaly probably would not be catastrophic in flight, although the pilot would feel the aircraft maneuver in a very coarse stair-step fashion. A software filter was added to the programming to smooth out the actuator movements. This suggested two things to future digital control efforts: a high-fidelity simulator with actual hardware and software is of critical importance in verifying the total system, and software can often overcome hardware deficiencies or idiosyncrasies.

When the actual flight tests finally took place, they were almost anticlimactic. In 42 flights totaling 58 hours, the digital system operated without a failure or restart. Pilots could choose to fly the F-8 in either "direct" or "stability augmentation system" (SAS) modes. The latter provided feedback to automatically reduce the piloting task. Test pilots could even fly direct in one or two axes, and SAS in the remaining axes. This part of the program paved the way for using digital systems to improve pilot performance in difficult-to-fly aircraft or spacecraft of the future.

Transition to Phase II: Testbed for the Space Shuttle

While the F-8 made aviation history at Dryden, NASA prepared for its next manned spacecraft program—the Space Shuttle. The concept of a reusable spacecraft dictated that the ►

vehicle should have the ability to control its movement through the atmosphere to a much greater extent than was possible in any previous manned program. To manuever during the glide portion of each Shuttle mission, the craft needed a control system for its moveable surfaces. Having separate control systems for space and the atmosphere would be unnecessary duplication. Therefore, a single digital fly-by-wire system would function in both space and during descent. The system became a fully integrated avionics system with a core of five general purpose computers involved in all spacecraft activities from launch processing to powered flight, on-orbit operations and reentry, glide, and landing. Not only would there be no mechanical backup to this system, but no analog backup as well. This meant that the reliability of the primary system had to be extremely high, and that redundancy had to be established within it. In 1973, a three-computer configuration was chosen for the F-8 Phase II hardware. A fourth computer was selected for backup. At the time, a similar hardware scheme was being considered for the Shuttle, so a triplex system on the F-8 would give the Shuttle program a convenient vehicle on which to test both synchronization and redundancy management techniques.

Contributions to the Shuttle Program

The Phase II of the digital fly-by-wire program contributed to the Shuttle in several ways, at least one unplanned. The planned ways included computer synchronization, redundancy management, and the demonstration of data bus concepts that reduced the hardwiring necessary in the control system. The need for redundancy in both the F-8 and Shuttle was due to the fact that each used a mass-produced, off-the-shelf general purpose computer, the IBM AP-101. Because the Shuttle would not have a back-up other than another computer of the same type, it was important that the avionics be able to function if one or more of the primary computers failed. Therefore, graceful reconfiguration of the primary system in flight depended on identifying whether a computer has failed and identifying the failure of any other mission-critical component (such as an actuator) so that its back-up could be engaged.

One way to determine whether a computer has failed is synchronization. Because only one computer is needed to perform all the functions of controlling the F-8 or the Shuttle, the same program can run independently in each of the computers in the system. By starting the computers simultaneously, each computer in the set should be at the same place in the software at the same time, with leeway for minute differences in hardware. In both the F-8 and the Shuttle, discrete signals are sent to each of the other computers at predetermined intervals. When the software is interrupted to check for synchronization, each computer sends a discrete signal to the others. The computers wait for the incoming signals, reset the count on the discretes when both arrive, do a second read to check if the other computers did their resets properly, and then reset the interrupt clock timing the interval between synchronizations. If the signal from another computer does not arrive within a specified time interval, or is incorrect, the waiting computers send a message declaring the delinquent computer "bad" and go about the business of flying the airplane. The failed computer can try a restart, declare itself bad, or keep on, but the other computers ignore it until it properly synchronizes. A failure of two computers causes an automatic switchover to the back-up control system. This entire process is done in less than 10 milliseconds, so short a time that the performance of the aircraft is not affected. The Shuttle system uses four computers in a redundant set instead of three, three discretes instead of two, waits 4 milliseconds instead of 10, and stops on software cues rather than a count, but the concept remains the same as the method used on the F-8.

The failed computer can try a restart, declare itself bad, or keep on, but the other computers ignore it until it properly synchronizes.

Redundancy management is another area in which the F-8 program directly contributed to the Shuttle. Many subsystems on both the F-8 and the Shuttle are triplicated, not only the computers. Signals from each of the three versions of the subsystem must be analyzed for error. The algorithm for evaluation consists of simple rules: if no failures, take the middle value of the three signals; if one failure, average the signals. Because the processes in the AP-101 could be scheduled, two periods of redundancy management were built into each software cycle. One period is used to make the signal selection, the next for fault detection; thus, failed channels are identified before the succeeding cycle begins.

An unplanned area in which the F-8 program contributed to the Shuttle was in the evaluation of pilot-induced oscillations that appeared on the fifth approach and landing test (ALT) flown by the shuttle *Enterprise*. After the problem with pilot-induced oscillations appeared, a series of test-flights of the F-8 was scheduled to try to replicate the problem and experiment with solutions. These tests provided needed data to develop a solution.

Proof of how the Phase II program helped the Shuttle was that out of the four computer failures in the first 50 flights, none caused a switchover to the back-up system, and none caused any noticeable degradation in the handling characteristics of the aircraft. Therefore, the purpose and efficacy of a multiple-string digital system was proved.

Wider Applications of the Technology

The F-8 and Shuttle are contributing to the development of a new flight technology, the Control Configured Vehicle (CCV), which incorporates digital fly-by-wire. The F-16 uses active control by an analog system and is being converted to digital fly-by-wire in the F-16/D models. The Navy's F/A-18 fighter also uses a digital fly-by-wire system. In the United Kingdom, a *Jaguar* fighter is part of a project to test a quadruplex digital system, and data bus concepts are being incorporated on new commercial aircraft as well as military planes. An aircraft that directly benefited from the digital fly-by-wire project is the X-29 with forward-sweeping wings. First flown in December 1984, the plane uses Honeywell computers with the same basic control laws and redundancy management scheme developed in the digital fly-by-wire program. All of these projects have proceeded with confidence because in the early 1970s an F-8 borrowed some space-age technology and repaid the loan with interest.

James E. Tomayko is an Assistant Professor of computer science at Wichita State University, Wichita, KS. He teaches courses in software engineering, distributed computing, and the history of computers. Currently he is under contract with NASA to write a comprehensive history of the Agency's use of computers in space flight operations. □

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Suppliers Forecast

Guildline Instruments, Inc., Orlando, FL, has developed a digital platinum resistance thermometer with a temperature range of -200 C to +600 C. The 9540 B has an IEEE 488 GP-IB interface for systems or laboratory application.
Circle Reader Action No. 329.

Flexible Computer Corp., Dallas, TX, offers the FLEX/32 Multi Computer, with parallel processing designed for real time systems. The FLEX/32 supports ADA, C, and FORTRAN languages and has UNIX System 5 capabilities.
Circle Reader Action No. 326.

Systems Control Technology's (Palo Alto, CA) Model C software facilitates modeling, analysis and control of dynamic systems. Block diagrams are drawn with a mouse.
Circle Reader Action No. 327.

Microcompatibles, Silver Spring, MD, adds the IBM-compatible Printmatic FORTRAN-callable printer driver to their graphics software line. Printmatic allows users to access the full capabilities of a dot-matrix or laser printer.
Circle Reader Action No. 328.

Honeywell's Tabular Monitoring software package pretests monitoring options for transducer activity review. The package includes online data and derived (real-time) channel monitoring, and alarm condition recognition. The software can be installed on Honeywell's H.TMS 3000 Test Management Systems. **Circle Reader Action No. 301.**

KineticSystems Corporation has a new CAMAC serial highway system for long distance ultra-high-speed data acquisition and time-critical process control. KineticSystem's distributed I/O format allows data transfer within a single Serial Highway message, providing transfer rates five times greater than other real-time highway systems.
Circle Reader Action No. 333.

TRAQ Technology Inc., of Baton Rouge, LA, introduces TRAQ-NET, a "smart" data collection system that processes data for dBase III files. TRAQ-NET links up to 999 data capture devices in a multi-sharing network. Information gathered through the terminal and software can be communicated to a PC host immediately or stored at the work station for communication to the host at a more convenient time.
Circle Reader Service No. 330.

Inference Co., of Los Angeles, CA, offers expert systems technology for a new line of computer Integrated Manufacturing (CIM) products under development by **American Cimflex Corp.** Inference's new products can be used for plant-floor control and information management at the automation workcell and machine levels.
Circle Reader Action No. 331.

MARC Analysis Research Corporation, Palo Alto, CA, produces nonlinear finite element analysis software that simulates the effects of heat and stress on products and manufacturing equipment. MARC's companion graphics interface program, a pre-and post-processor called MENTAT, generates models enabling users to 'see' the results of an analysis. The MARC/MENTAT combination runs on a wide variety of computers, including the leading engineering workstations. **Circle Reader Action No. 323.**

Applicon, a Schlumberger company, introduces their 68020-based Bravo3 Manufacturing Workstation, a 32-bit UNIX system with a 19-inch high-resolution monochrome graphics screen. A mass-storage subsystem enables operation as a stand-alone unit or as part of an Ethernet-TCP/IP network. Included is the COMPACT II Numerical Control programming language, a 2-D graphics system for blueprint creation and other mechanical and process documentation.
Circle Reader Action No. 308.

Aptec's recently introduced I/O Computer, the IOC System 200, a special-purpose input/output computer, accelerates the throughput of I/O-intensive applications on DEC's VAX/VMS minicomputers in excess of 50 times. In a typical application, the IOC efficiently supports up to a dozen high-performance peripherals and devices. It provides a 200 Mbytes/sec internal bus, programmable 12 Mbytes/sec I/O processors and high-speed mass memory with access rates up to 50 Mbytes/sec per memory board. **Circle Reader Action No. 310.**

Gold Hill's new 386 LISP System includes the HummingBoard, a 386-based plug-in board with up to 24 Mbytes of directly addressable on-board memory for IBM PC XTs and ATs, and the Golden Common Lisp (GCLISP) 386 Developer. The HummingBoard serves as a co-processor capable of executing GCLISP programs five times faster than an IBM AT. The GCLISP 386 Developer is a Common LISP programming environment used for development and delivery of AI applications. **Circle Reader Action No. 311.**

Nicolet Test Instruments (formerly Nicolet Paratronics) announces four new dedicated probes for its 800 series logic analyzers, which support the 68008, 68010, and NSC800 microprocessors, and the IEEE-488 bus. The probes easily connect to the test unit, and disassemble collected data into microprocessor or GPIB mnemonics. All models include high impedance buffering, qualifiers to purge unwanted bus cycles, and disassembly software. **Circle Reader Action No. 313.**

R.R. Software, combining microcomputing and military/industrial contracting, offers products and services for microcomputer-based Ada. Janus/Ada, a compiler line for 16-bit systems, and PasTran, an ANSI STD Pascal to ANSI STD Ada translator, were released in 1982. The company also sells other Ada related products, including an Ada tutorial, an embedded systems development package, and Ada application programs ranging from an editor to complete graphics capabilities. **Circle Reader Action No. 314.**

Control Data Corporation announces two 1750A computers for the space and avionics markets. The computers will be based on Control Data's two-chip CPU running over 2 MIPS using the standard DAIS floating point instruction mix. The CPU has received U.S. Air Force certification. Full form-fit and function engineering units will be available in the second half of 1987. **Circle Reader Action No. 306.**

Data Precision's new 640 Module and High Speed Sampling Probe, with the DATA 6000 mainframe, can make high speed, high precision measurements to 100 GHz equivalent time sample rates with 16 bit resolution in the 1 GHz bandwidth. The probe can measure fast rise and settling times by digitizing data points 10 psec apart.
Circle Reader Action No. 307.

Digital Equipment Corporation and Systems Designers signed a development agreement to share their Ada technologies and build a family of cross-compilers based on Digital's VAX Ada programming language. The cross-compilers will support the MIL-STD-1750A, Motorola 68000 and Intel iAPX86.
Circle Reader Action No. 324.

MASSCOMP's (Westford, MA) **Scientific Laboratory System (SLS),** a data acquisition computer system designed for laboratory applications, features RTUTM UNIX, for high performance, real-time scientific experiments. SLS includes Laboratory Workbench; mouse-driven software that eliminates programming through pull-down menus, pop-up displays, graphical icons and interactive controls.
Reader Action No. 318.

Visionics Corporation's (Sunnyvale, CA) EE Designer II CAE/CAD integrated software package supports surface-mount design and multilayer layout. The software has the ability to create ground planes on either side of PC boards. User-definable features include trace width and pad sizes, pin-snap, block delete, macro save and multi-step pan. Fabrication drawings can be created with related text through the software's text editor and automatic board-dimensioning capabilities. **Circle Reader Action No. 302.**

Defense Advanced Research Projects Agency (DARPA) awarded **Brimrose Corporation of America** a Phase II research grant to develop a Real-Time X-ray topography system for quality control evaluations of epitaxial films of gallium arsenide (GaAs), gallium aluminum arsenide (GaAlAs) and mercury cadmium telluride (HgCdTe) on various substrates in production environments. Potential applications include evaluating single crystal or large polycrystal substrates and epitaxial film materials. **Circle Reader Action No. 312.**

Boeing Technology Services' (Seattle, WA) Flight Systems Laboratory (FSL) has developed the new direct technical support for programs or contractors, and can serve as an advisor, consultant or auditor. FSL also provides the New Simulation System (NSS), uses parallel processing architecture to develop more realistic flight simulators.
Circle Reader Action No. 319.

Fluoramics, Inc., Upper Saddle River, NJ manufactures Compu-Lube, a lubricant marketed for use on fine mechanisms on computers. Also new is Tufoil, an oil additive that lowers mechanical friction. Tufoil's chemistry includes suspended PTFE, or Teflon microparticles, giving it a friction coefficient of 0.02 on the National Bureau of Standards' steel-on-steel 4-ball test. **Circle Reader Action No. 320.**

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